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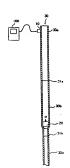
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### (54) [発明の名称] 拡管時の品質監視方法



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### 【特許請求の範囲】

「結本項」 一個行の地では、「議解での服動を検出する 人モセンサを開発に当該させて設け、拡管マンドレルが 解答の内部を移動したがら地管する際に、人にセンサ信 りの臨場が増大したこと、人にセンサ信りの臨場の増大 した円数率しては人にセンナ信号の転場の増大した時間 を検加し、その傾加に分に基づいて前途開発の意門第 の発生を押定するようにしたことを特徴とする起発時の 記憶を加

【請求項2】 前記品質異常を何定した際に検知される AEセンサイゴラの振幅の入きき。AEセンサイゴラの振幅 が増大した内板料してはAFセンサイボラの振幅の増大し た時間に基づいて前記網管の品質異常の程度を複定する ようにしたことを特徴とする請求項1に記載の拡張時の 品質と観力能

### 【発明の詳細な説明】

### [0001]

【発明の属する技術分析】本発明は、配管時の品質監視 方法に関し、特に長代の類似等を拡架するときに顕常の 単目等に発生するクラックやピンホール等の品質異常を 電視するのに好適な拡管時の品質監視方法である。 【0002】

「従来の採用」後来、例れてよる長尺を必然等するに思 しては、総等マンドレルを使用して拡守することが付か われている。これは、例はご示したように、長人管30 の 力の関ロ協より拡管マンドレル20を挿通し、研究 の商車単を利用しての総等マンドレル20を挿通し、研究 のに押し込むことにより、長人管30の内等面を予加へ 即丘し、能答していくものである。

【0003】ところで、この総管加上によって報管に回 えばしび私かのような出質原系が整生する場合がある。 報に、例えばノカジョイント、密接次1年地接接合等による場合を分を有する解管の原発にはでは、このような品質資深を使してすい、このような品質資深を修 出するために、様文、例えば、超質数を解除者体に必執 し欠陥而を基準と収割減が適により、内部がにより、内部がな 見する信息設定に出せ、別的体化に欠終をすてて、その 信急的対象とフェルが送こませて、その場で使のである。 を解析してく収定を示さ、このよりなといった。」のは、 を経過による。

【0004】しかし、これらの検査方法を行なうには検 煮装置の少なくども一部分を検査したい部位に設置させ なければならないどいう構題があり、これは、観答が良 くならはど人きな問題となる。また、これらの検索力が では、純価作業中の部位では行うことができず、少なく とも検査部域の観音が終 代した後に行なわなければなら ないという問題もあった。即ち、従来の検査方法では、 統管をした後に、検査する時代に検査装置の少なくとも 一部を収収して検査を存在から必要があった。

10 0 0 5 3 · ブ、花米、原下の小師のを扱い上げるための前非用ハイブを設置するにあたり、その形況コストを下げるため、他の比較的小さい網帯を地中に併入した後、比略マンドルバ等を制止で使力からの即形により師めませて記憶すると技術があれている。このように表するされて顕著を表現でいるため、無質なの情報があり、検査装置を制容の外壁にあって長さら声に保勢させることは実に同様であったため、興労の所能を検査装置を保持あさせて存立すると参加あるが、批音後であってたさらもあるが、出音後であって大きなものであるが、は一般であったともあるが、出音後であって、オモモの全体について従来の力が正常は高度等を検索した。またその全体について従来の力法で高度異常の検査をすることは非常に関係するという関係があるという関係があるというにある。

#### [0006]

「基準的本権以上ようとする報酬」本等的の原係しようとする環動は、鋼管の配管作業中に管理機関的計算したが 他で網管の結算性配管性を制定することができ、結果では実際が、5個でも振りない。 関から属した間位の高質質素の発生又は程度を制定する とができ、かつ、非解音の高質素生生はほぼ時に その発化を検出することができる故管時の高質能更力症 を使用することにある。

### [0007]

「超越を検索するための手段」この超越をが戻するため に未受けに係る起呼りの上質を見かれた。 博うから に議解さの記動を検討する A E センサを解管に当体させ で設け、影響マンドレルが解すの内部を移動したがらい、 をする際に、A E センサルテルを開発の対象を移動したがらい、 をする際に、A E センサルテルを開発の対象によっしていませっ ようの電気のが見たした時間を検討し、その検知は37に基 づかて前記解音のが背景深の生生を利達するようにした ことを参修とするいである。

【0009】また、請求所2に記載の発明のように、前

記品資料を刊度した配に接触されるAFセンサポラの 転転の入らさ、A セセンサポラの配転が得入した回数器 しくはAFセンサポラの散転の増大した時間に基づいて 耐型層の品質異常の起度を刊度するようにすれば、耐 込みモセンサポラの転転の大きに思ついて前に無向 必有異なの起度を刊度でき、前記AFセンサポタの転 が増大した回数に基づいて消差顕常の品質異常の程度を 刊度することができ、非しくは、AFセンサポタの操 の増入した時間に基づいて消差的での監質異常の程度を の増入した時間に基づいて報音の監算異常の程度を の増入した時間に基づいて報音の監算異常の程度を同定 することができ、非しくは、AFセンサポタの提供 することができる。

【0010】実に、結末項3に記載の発明のように、花 電マンドレルが開発の内部を移動しながら紅管する際に 接出されるんじセンサの時をを増配すると共に、AEセ ンサはけの転転の連続的た場合に応じて値記期転の度合 を高め、AEセンサの顕転の運転的な増加に応じて前記 環転の度合を低下させるようにすると良い。

[0011] このように行かう本条列の治水率はこと数 の松平等の必見を関力がに上れば、松平マンドンへが 等の内部を移動しなから配管する限に破消されるんだセ ンサの付うを増加すると共に、松平によりを発する実施 さくなると前記機能の収金を増加させ、部記域最近電子 すると前記機能の収金を増加させ、部記域最近電子 でもと前記機能の収金を増加させ、部記域最近電子 で、松下により発生する最高が人とセンサまでに向する ことによって失じる被買が推正され、深細正された人と センサの等に長がている場合を表すなから

[00]21 ここで、増機の度合の変化を人とセンサ出 功能値の連続的な極少大は運転的な増加に応じて行かう こととしているのは、拡張により発生する振動の大きさ が比め値段が定じており入れモンサの出力動機が延続的に 変化する確認のが重要が表かすることを意味が が重整的が高限が定じったりは高速機械を運動を が整め的であるがにあっては高速機械を運動されている。 たとを重味する このように非連続変化が今極いた 人にセンサ信号機能の変化に基づいて輸出をすることに より、高質等容易を化して低が時期の入上に引きが 場所に得入又は乗りてしることが 、 概名を確保に動しても、

#### footol.

【保押の実績の形態】以下に本発用の対象が実験の形態 を関慮を参照して詳細に説明する。図 1 に、水平明に体 を解下の地で物から出管電視力がの概念を説明するために ホレ天観場構成限である。長火管 3 の については、物面 を基している。最大尺管 3 の に、比較的助い場所で は、3 1 b ・・・にはいては、対象 の にはおいては合われたものである。同じおいては、対象 の 3 3 4 なんないないないが、更にも方は続いてい

【0014】抵管アンドレル20は国家のようにデーバ 部分と円柱部分とを有し、後方(国面においては上方) から前足を負荷され、前/ (図画においては下)) だ 続行しながら前をデーバ湯がしまり 以外等の内容前を下 移方的方に押し起げて、前込長尺第30を数定するも、 のである (Alt ニンサー) ロは長尺等の分類値にに関する 状態で認定され、前記証券が行われているときのほ外側 前の転換を信号に変換するものであり、監視実置水化1 0 に接続されて振信を担かて振信。

[0015] 図2は、本界形に添加される品質度現実的の信息機関係を示す網がコックである。 の信息機関係機能を示す網がコックでである。 に同じ高質性視覚的ない。 1011機能が耐寒度等1011機能とか、現実制度が開始している。 011世段機能等103に機能され、異常制度が開始した。 定部1026世界度2103に接続され、比較地理部 1031任海州東度110日総能される。

[0016] 南陸穀和鑑取用紙1011在モンナ10 の地力信号の電が全板り幅を絶対単化した信号を出力 する。南起異常程度基準配配第102はAビセンナ1 のの信券編の力きさを相関するための関係である異常 均定基準億計1を設定する場がであり、異常有電基地 値下11は、異常なく整管が行なわれている時のAビセンサバ行を編と監督が発生したときAFセンサ係分 転程との間の確信集等が発生したときAFセンサ係分 転程との間の確信集等が発生したときAFセンサ係分 転程との間の確信集等が発生したときAFセンサ係分

【0017】例以ば、基準検定でつまるを設けて乾気針 来の瞬間の器間にじてずか実験的に得られた異常物定 基準値を機作者が設定するようにしても良いが、ここで は、独長を寄るのが収留加乏がかのた切削段階の時刻; まのたとセン時の影響が、までかっました機能。 1 (限し、k1>1) を楽じた値を自動的に設定するは にする。

1001 R1 制設比較級原轄10 03代、総対的処理集1 01か5人力も力な信号を創意業業等提集所能 日 10 20 元、総対極処理第10 11の場合が展示制な運輸値 日 16 超表で場合に高加金化信号を担かする、影加 度110代、制定高級を生信号を担かする、影加 度110代、制定高級を生信号が入りまれたときた。 、 質異高水産生化たものと物定し、その行を音声減い代表 示によって使用を活き動する。

【0019】このようにして、(a) に示すように構成 される品質監視装置本体100によって品質監視をすれ は、AEセンサ10の信号は両波分を除去され整識され 振幅を取得されて、AEセンサ10の信号機幅が異常利 定式能量を超くた場合に異常を4の情が否知される。

[0020] (b) に示す監督監視装置水を100円。 例からたかからよび、流産(20)に水平監督監視装置の基本の比較処理部104次下部等に104の開たへへのよ数部104次下部である。ベルショ数を3104円。比較機理部104次に対して成立に高速を終わる。そして、比較観報部104次に対したの間を手が過ぎました。 成を作りの開発を計数は、その制度を必要が出した向 様に行った現代に、高性異常化生の対象と対しません。 にでは、近代を200円を30円を30円を30円によった。

ときに、品質異常発生信号を出力することにする 【0021】従って、(b) に示すように構成される品 質監視装置本体:00によって品質監視をすれば、AE センサ10の信号は直流分を除去され整流されてその振 編を取得されて、AEセンサーロの信号振幅が異常判定 基準値を超えた回数が2回以上の場合に、品質異常発生

の旨が告知される

【0022】更に、この場合に、パルス計数部104 は、前記品質異常発生信号に加えて、高値発生信号の回 数を告知手段110に伝送し、告知手段110は品質異 常発生の旨及び高値発生信号の回数に応じた品質異常の 程度を告知するするように構成しても良い。例えば、高 植発生函数そのものを告知するようにしても良いが、こ こでは、2回ない1.3回の場合には果菜の程度が「頭」

である旨を、4回ないし5回の場合には異常の程度が 「中」である旨を、6回以上場合には異常の程度が

「強」である旨を告知するようにする。

【0023】 (c) に示す品質監視装置本体100は、 (a) に示す品質監視装置にピーク値検出部107を増 設したものである。ビーク値検出第107には絶対値処 理部101の出力及び比較処理部103の出力が入力さ れると共に、告知手段110に接続される。ヒーク値検 出部107は、前記比較処理部103から前紀高値発生 信号が出力された場合に、そのときの絶対値処理部10 1の出力のピーク値を保持し、前記告知手段110に出 カする。

【0024】そして、告知手段110は、品質異常の発 生の行及び前期ビーク値に基づいて品質異常の程度を告 知する。例えば、ヒーク値の大きさそのものを告知する ようにしても良いが、ここでは、ビーク値の大きさによ り異常の程度を「強」、「中」又は「窮」に判別し、そ の判別結果を告知するようにする。

【0025】 (e) に示すように構成される品質監視装 置本体100によって品質監視をすれば、AEセンサ1 ()の信号は直流分を除去され整流されて振幅を取得され て、AEセンサ10の信号振幅が異常報定基準値T h 1 を超えた場合には、異常発生の行と該品質異常が発生し たときのAEセンサ信号機幅のヒーク値に基づく品質器 常の程度とが、音声又は表示によって通知される

【0026】(d) に示す品質監視装置本体100は、 (a) に示す品質監視装置の絶対値処理部101と比較 処理部103との間に包絡線接政部106を増まし、比 校処理部103と告知手段110との間にバルス幅判定 部11)8を増設したものである。前記包格線検表部10 6は、絶対値処理部101の出力信号の各権大値を結ぶ 包箱線信号を出力し、比較処理部103に伝達する。比 校処理部103円、包箱線検波部106の出力が前記署 常判定基準値でも主よりも大きい時に高値発生信号を告 知手段110に出力する。ハルス福刊定部108は前期。 高値化生信号の時間が所定の時間よりも長いときには、

異常発生の旨及び前記高値発生時間の長さを告知手段」

10に伝達する。

【0027】そして、告知手段110は、品質異常の発 生の旨及び前記高値を生信号時間の長さに从づいて品質 異常の程度を告知する。例えば、前記高値発生信号時間 の長さそのものを告知するようにしても良いが、ここで は、前紀高値発生信号時間の長さにより異常の程度を 「強」、「中」又は「弱」に刊別し、その判別結果を告 知するようにする。

【0028】(d)に示すように構成される品質監視装 置本体100によって品質監視をすれば、AEセンサ1 0の信号から直流分を除去され整流された信号の包絡線 強度が異常判定基準値を超えた時間を計劃し、核時間が 所定の時間よりも長い場合に、異常発生の旨と包絡線後 度が異常判定基準値Thlを超えた時間に基づく品質異

常の程度とが、音声又は表示によって通知される。 【0029】 図3は、図2(a)、(b) 及び(c) に 共通する各処理部の信号波形を概念的に示した図であ る。図3は、具体的には、図1に示す品質監視構成にお いて、拡管時に接続部31bで品質異常が発生した場合 の品質監視装置本体100の各部で出力される総形を示 したものであり、(a) はAEセンサ10の出力信号を 示し、(b) は絶対値処理部101の出力信号を示し、

(c) は比較処理部103の出力信号を示す。 【0030】(a)に示す波形を順に説明する。時刻 t 0に拡管マンドレル20の進行によって拡管加工が開始 すると、該進行時の拡管マンドレル10と長尺管30と の摩擦による振動及び拡管による無性変形等によって生 じるいわゆるアコースティックエミッション (AE) に よる振動等(以下、これらをまとめて拡発振動とい

う。) が発生する。この拡管接動は品質異常が発生して いない場合には、比較的弱い発性波である。従って、鋼 答30 a の拡管中である時刻 t 0 から t 1 までの時間に は、AEセンサIOは比較的小さい振幅の信号波形を出 カする.

【0031】次に、接合部31aの拡管をする時刻±1 から12の時間は、該接合部31ヵは例えばメカジョイ ント、拡散接合、溶接等により接合されており、その硬 度が鋼管30aよりも高いため拡管マンドレル20の進 行が遅くたり、前記鉱管振動は、更に濁い振幅の振動と なるため、この時間はAEセンサ L Oは時刻 L Oから L 1よりも小さい振幅の信号波形を出力する。鋼管306 を拡管する時刻12から13までの時間には、前記時刻 LOからし1までの時間と同様に、AEセンサーのは比 較的強い振幅の信号波形を出力する。

【0032】そして、次の核合部316の転管中にひび 割れが発生すると、その破壊によりエネルギーが確認さ れ比較的大きな振幅の発性波が生じる AEセンサ10 ご該弾性波を含む枢管振動を検出して、時刻13から1 4の時間には、比較的人きな振転の信号被形を出力す

ろ、以降、図からわかろようにAEセンサーロに、解答 31 とを起答する時刻し4からし5の時間には比較的小 版稿の信号故形を、図示しないその次の複合部を拡管する的刻し5からし6の時間は更に小さい振幅の信号故形 を卸力する。

[0033] 一方、松対面原理は101の対力版例は、 (a) に示すたビモンサ出力の高級分を除りた総合体化 したものであり、(b) に示す如き機形となる。また、 比較処理部1031(前途配対低処理部101000万億 分を開送のように記定された異常可以表格値で111と比 校して、該基準値で111とりも大きいときには「[113] を用力し、該基準値で111とりませたときには「[113]

【0034】従って、比較処理部103は、(b)に示す絶対値処理部101の出力信号が入力されると、

カする-

(c) にネマ波形を出力する。時刻10から13の時間 は、熱質値製用に10からは高度実質で基本を電子目 1よりよきな入力がないので出力は11より、10分まで ある。また、間が20分まりに対象13から14の時間にひび終れた役主するので、(b) に示すように、前定異常 付定基階級711より5人となる幅の所分が入力され、 (c) において行動13から14の時間に、パルスド1

(c) において時刻に3からし4の時間に、バルスP1からP3を出力する。検いて、時刻し4からし6の時間は、前尾基準値でH1よりも大きな入力がないので、再び「Lo」のままである。

[0035] 図2の(a) ないし(c) の構成を有する 高質性限度が作り00分をは、これの別3(c) ないし(c) にポイ州が居じまないて、次のように処 整やする。図2(a) にポイニの変投投資本作り00 は、比較処理部103か51付1) のバルスが出力され たので、実知手段110~緊急発生信ぎを免し、実知手 段110が異常の後半を管加する。

10036 [ 図2 (も) に赤子品質性限装配本体100 は、比較処理部103から出力されるバルスの回数が3 阿であり、2回以上に終当するので高質異常生の行を 当知する。また、高値発生信息であるバルスの回数の3 回に対応する高質異常の程度を告知するようにしても良い。

【00371 図2(c)に示す品質優展素本作100 に知いては、ビック解集部のでは、共発機関で 3から 月は11 を分がら即用力されるので、大々のから 名を理事の場合機関係 101の出力のビータが上 ないしPK3を検出し、告知で使110に異常を生むう 及びビーク値PK1ないしFK3を依える信号を伝達さ と、判断では101に、指揮変が変化の得及が高速 に一ク値PK1ないしFK3におはする監督収置の場面の 度をしているというにより表する。

[10038] 図4は、図2(a)の各処理部の信号鉄形を概念的に示した図である。図4は、特体的には、図1 に示す品質監視構成において、振管時に接続部の18で 品質量素が発生した場合の高質性限契則を採り合のの各 部で出力される厳制を示したものである。(a) はA E センサ1のの形力局を示し、その機能は図3 (a) に 等しい。(b) は絶対値処理部101の出力信号を示 し、その表形は図3 (b) に等しい。(c) は包格制能 級部106の形力機能をおいい。

[0019] 限20(4)の構成を行する高質整限数 本体100は、図4に2寸に5寸に基づき、次のように出 質異常を検出する。比較更増加103及びパルを相判定 第108により包積製造度の指移を可置し、接急積軽 成が高度気管制度単析的下110人とい明日(比較 起増加103が総定端接を伝わりで出力する時間であ り、図において下でされる。)が所定の時間よりも比 い場合に、実知手段110に異常免化的及心能呼明 下を伝える信号を伝達する。当知手段110は、高度製 ののその背を伝達する。当知手段110は、高度製 でのその背を伝達する。当知手段110は、高度製

の程度を、音声あるいは表示により代謝する 100401 図511、図2(3) ~ (4) に示した解析 高質監視気料の処理構成例を示す納御プロック図で ある。AEセンサ10は、超起及内質30に有效され、 長尺質30の成型の原動を係りで変し出力する。 総理理部101は、AEセンサ10の出力信号の高気分 を除ました信号の総対信と解説理部105及び回路線 検索前106にカナラ。

【0042】 包納線検整部 10 6は、 絶対絶処理第10 1の由力は方の全棒人後を結ぶ位内線に所定の処理を た信号を出力し、同線規算項10 5 に伝達する。ここ 11、後に算速するように、日体となる軸管 30 a、30 b、30 c・・・の拡張的であり実際が発生していない。 時の人をセント門の原版を前近機直接補での可能とす るように、包絡線を処理して均幅処理第10 5 に用力す

【0044】前記比較処理部103円、増編処理部10 5から入力される信号を前記異常前定基準値下12と比 校して、増編処理部105の信号が開落制定基準値下4 2を増えた場合に高値化生信号を用力する。借知手段1 1 0は、前記高値発生信号が入力されたときに、品質異常が発生した旨を音声或いは表示によって操作者に通知

[0045] 図6及び図7は、図5に示す各処理構成部 の出力を観念的に示した波形図である。具体的には、図 1に示す構成で長尺管31の処管を行なって、複合部3 2もでひび暮れが発生した場合における。図5に示す処理構成の各種の円力表形図である。

100 47] 検いて、顕常30 bの蛇をそけなう時候、 なから13 生での時間には、前記時刻10から11 まで の時間と同様に、A ヒセンサ10 は比較的強い 転輪の信 号数形と出力し、接合能31 bの起管ででありび7時机 水発生なら時間はは、比較分大きな 転幅の信号数形を出力する、以降、顕常30 cの能管を 行なつ時間10から15の対策には比較的小輪軸の対象 数形を(現本しないそのたの形を影を整常する時間15 から16の時間12更に小さい最極の信号変形を出力す。

1004年1 図4 (お)に示す変形は、絶対動処理部1 01の出力店号であり、AEセンサ10の出力店号の直 次分を除立した信号を絶対値化したものである。図6 (c)に実称で示す変形は、包格線検索部106の出力 信号であり、絶対前処理部101の出力の包閣線を次の ように動電したものである。

【0049】即5、時刻にから時刻に、時刻にから時刻を発力した時間は表皮が特別をあからしたの時間に、長月を を時刻は人変が対しまからしたの時間に、長月を を時間とは異常が発生している時間の数色無難は回信 でした破離で示す変形になるが、これらの時間については近線を示す変形になが、これらの時間についてはは後継で示す変形になが、これらの時間については対象で不対したが、例とは時段を の解剖の足解解膜の変化から振りと対して異常で示す。)を近当時初の直解を強度の表化から振りとが表している。

10050 開発は、高点は集めの独保線の連絡から東めた事情的と実際の結構的との意义は比が再定の範囲を超えた場合には、実実開始の代わりには手間的をもわいるように平ればよい。このように平れば、後後部の総合の自分の集合を発生しなの場合を発生しなの場合を発生しない。これらの時期の包含容器度の代わりに高点を開始される時代という。これらの時期の包含容器度の代わりに高点を開始が表現している。

【0.05 (1] 図7 (a) は、増幅処理部1.05の出方に 分である。この出方は、増幅処理部1.05が、AEセン サには、弊性表の域長を補止すったがに、図6 (c) に 実験で示す負務網接数部出力の強度に度比例する時報は で、最終値数理部 0 1 が月カナを図6 (b) によず信 号を開催した結果である。図がらもかから力に、明確 処理事 1 0 5 は最後前機型第 1 0 かほうと骨軽する度 合き、拡管中の部位からAドセンサの下機が導れるに応 じて高か、試管による操作業の検収を適縁に補正して出 カオる

【0052】図7 (b) は比較処理第103の出力信号を消失。比較処理第10日は精磁処理部の出力が消急で 京判定基準値下12を超支むときに「日1」信号を出力 するので、対領13から時候14の時間に、高級条単保 うである小ルス的ドリアカビリンが出する。今年 11日は、該高級条生信号を受けて、基督異素の発生を 千尺以表示により適知する。

[0053] 更に、前記比較回路部103と前記的如手 設110との間に、パルス計数処理部を設け、比較処理 部103からの間高温解彙化信息の回覧を計数し、その 関数を告知手段110に伝え、常知手段110は高質異常の 報象をの再及び認例象性信がの函数に応じた高質異常の 税を告知するとうにしてもよい。

【日の15-41 一力、前記比較関係103からの本稿及生 信号が出力されたときに、その直後の増幅図路田力の検 大盤を検出し、その値をり助手段に伝えるピーク値検出 部を設け、告知手段110は品質異常発生の旨及び該ヒーク値のおきさに応じた品質異常の対度を供加するよう にしてもよい。

【0055】関係は、開発を実際に発発してひむ終わが 発生したときの外短端の出力放形例である。具体的に は、図す及び図2(a)に記載の構成によって、本発明 による品質監視を実際に行なった場合の出力疾形例であ る。(a)において、が執い、削減、時期、2 前後、時 別13前後に発生する大きな振動の出力疾形は、3 の時間に、Oび割れが発生したために生じたものであ

【0056】関からもわかるように、総定異素的定基件 整数変部102元。 前定異常物定基件配下 1 を整質物 別の時候1、における人ドセンサの製紙A \* 50元倍の値 に設定すると、比較処理部103比(も)に示すように 前定が簡単化でもあるパルスでラを軽減11分を終すした。 同、時刻12付近に2回、時刻13に3回発生する一定 って、当期予度110以、これらの時候11、12又比 13に異常発生の好を告加する。

[0057] 本集別は、前辺した実施の形態に何ら原定 まれるためではなく、本集明の場合を創したい。範囲で 様々の改変が可能である。何まは、監視対象と大る例で は低音器を有するものに関われないことは、ようまでも、 ない、AEととつの現代様がは特別の側に限ったす。 薬剤に取り付けでもよい。また、前記と幾のが形では、 統管シンドレルをという場合を有する数値でとりとしょと したが、これに限られるわけではなく、例えば、マンド レルの外側面に接送ローラを有し、該舷径ローラにより 網管内壁を半常方向外方に押し広げて拡管を行なう構成 の拡管マンドレルとしても良い。

【0058】・万、前足製売料定基準的の設定について も実施の形態で何味した原理に限られて、異常なく起答 が行なわれている時の判定対象となる信分の転離との間の 値になるように設定すればよい。更に、前定実施の形態 において、アナッグに分類では、前定実施の形態 を、デジタルは分更壁により行なうようにしてもしい。 例えば、絶対後処理により行なうようにしてもしい。 の表は、総対後処理により行なうようにしてもしい。 の表は、総対後処理にもり、は70歳後規準に105 後に入/10コンパータを数けてその出力をデジタル信号 に変換し、以降の也理をデジタル信号処理により行なう ようにてもまし、以降の也理をデジタル信号 かましているまた。

[0059]

【契則の効果】 本祭りの法中項 「にななの証管中の品質 総製力店によれば、就管マンドレルが移動して起管をす るときには、第二統管部位で職動が発生しており、鋼管 に結算資本が発生した際には、私ビセンサ付け原配がそ の間後の時刻の映線よりも、かなことを利用したも のであり、温管役長のために特別に動脈装置、関射装置 等を設けること々く拡管等の品質異常の発生と判定する ことが可能であるという効果を有する。

[0060]主た、かかる監管装置が移動及び拡管する とさに発生する機動は、総管 ている部位から機能なた位 設定あるたとセンサまで網界を伝搬して無くので、 製理企体が一定の場所に静止した状態で起きのの場で 総を行なっととが確定もか。 DRの網のを配答 時の高程定制が「低であるという効果をする」 更に、 環際動作機能する速度は非常に述いので、 起管によって 例えばびびがれなの高質質素が発生したときには、発生 とほぼわりに高度質素の発生はでの過程異素の印度を 総則することが確定もある。

[0061] 東に、清水南とに記載の途告別の高電電視 力法によれば、清水南」に記載の高層電視方法の効果に 加えて、高質転換のために特別に動脈気滞、無型製置等 を設けると要かなく、監視展置を体が、完め場所に静止 した状態で、高質質等の発化と社(は四回に、高質異常の 程度を検定することができるという効果を奪する」

【0002】また、請求項目に対し飲料の需要収力 加によれば、人にセンサビリの構動の減失的た場合に応 せてれませったの職の場合をあり、人にセンサビリの動動の場合を 形下させるようによって、影響によって「ころが が入ませっサビ版」までの減くをはおいて補可しるこ を示さる。まれてコリビックはいて補可しるこ を示さ、まれてコリビックに対して補可しるこ を示さ、まれてコリビックに対して補可しるこ を示さ、まれてコリビックに対しては、対して

【0.0.6.3】何えば、拡管マンドレルがAドセンサから

離れている場合にはAFセンツ以分の町でが補正とれる ので、より長火の解管においても球束性の高い品質質素 の発生の物定及び高質異常の程度の判定が可能になる。 また、に額距離の変動によるAFセンツに分縁起の変動 が小さくたり、結質異常の要生の利定及び結び異常の低 度の制度の感覚が定定するので、これらの利定の信頼性 を高めた複常時の島質繁度方法が提供されることにな そ。

#### 【図画の簡単な説明】

【図1】 本発明に係る鋼管の拡管時の品質監視方法の概 会を適用するために示した概略構成図である。

【図2】本発明に適用される鋼管品質監視装置の信号処 理構成例を示す制御プロック図である。

【図3】図2 (a) 、(b) 及び (c) に共通する各処 理鄰のほう被形を概念的に示した図であり、 (a) はA Eセンサの出力信号、 (b) は絶対質処理部の出力信 号、 (c) は比較処理部の出力信号を示す被形図であ る。

[図4] 図2 (d) の各処難部の信号被形を概念的に示 した図であり、(a) はAFセンサの出力信号、(b) に絶対値処理部の出力信号、(c) は包格料検波部の出 力信号を示す数形図である

【図5】図2 (a) ~ (d) に示した鋼管品質監視装置 以外の処理構成例を示す制御ブロック図である。

【図6】図5に示す鋼管高質整視装置における各処則結成部の出力を概念的に示した被影響であり、(a) けれ Eセンサの出力信号、(b) は絶対値速理部の出力信号、(c) は包結線検波部の出力信号を示す波形図である。

【図7】図5に示す納管品質整視装置における各処理構成器の用力を概念的に示した波形図であり、(a) は増 機処理部の用力信号、(b) は比較処理部の用力信号を 示す波形図である。

【図8】鋼管を実際に拡管してひび割れが発生したとき の各処理部の出力波形図であり、(a) は絶対値処理部 の出力波形図、(b) は比較処理部の出力波形図であ

【符号の数判】 10 AEセンサ

10 バミセンサ 20 拡管マンドレル

30 長尺管

30a, 30b, 30C, · · · 解管 31a, 31b, · · · 接合部

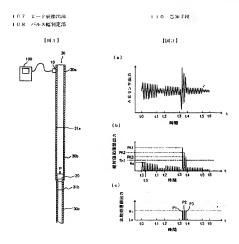
100 品質監視装置木体

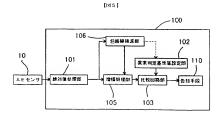
101 絶対観処理部 102 異常判定基準値設定部

103 比較処理部

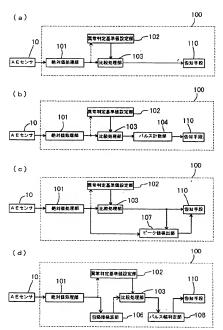
104 バルス計数部 105 増幅処理部

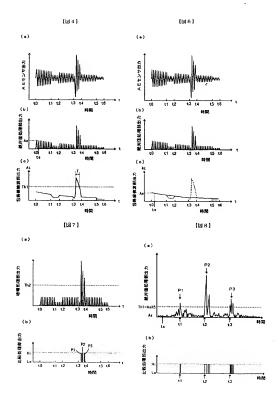
106 包紹線検波部











フロントページの続き

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	Continued on last page

(54) {Title of the Invention} Quality Inspection Method for Use During Tube Expansion

### (57) {Summary}

(Problem)

To offer a quality inspection method for expanded tubes whereby the occurrence of quality aberration or the degree of quality aberration can be determined at the time of expansion of the steel tube, and whereby remote observation is possible.

(Solution) An AE sensor 10, which detects steel tube vibrations during tube expansion occurring as a tube expansion mandrel 20 moves through the interior of a steel tube 30, is situated against the steel tube. Increases in the AE sensor signal amplitude, the number of increases in the AE sensor signal amplitude or the time over which the increase in AE sensor signal amplitude occurs is detected, and the occurrence of quality aberration or the degree of quality aberration in the aforementioned steel tube is determined on the basis of the detected signals.

[see source for diagram]

### {Scope of Patent Claims}

[Claim 1] A quality inspection method for use during tube expansion, characterized in that an AE sensor for detecting vibrations in a steel tube during tube expansion of said steel tube is situated against the steel tube, and when tube expansion occurs as a tube expansion mandrel moves through the interior of the steel tube, increases in the AE sensor signal amplitude, the number of increases in the AE sensor signal amplitude or the tune over which the increase in AE sensor signal amplitude occurs is detected, and the occurrence of quality aberration in the aforementioned steel tube is determined on the basis of the detected signals.

{Claim 2} The quality inspection method for use during tube expansion according to Claim 1, characterized in that the degree of the quality aberration in the steel tube is determined based on the magnitude of the AE sensor signal amplitude, the number of increases in AE sensor signal amplitude or the time of uncrease in AE sensor signal amplitude.

(Claim 3) The quality inspection method for use during tube expansion described in Claim 1 or 2, characterized in that the AE sensor signal that is detected during tube expansion is amplified as a tube expansion mandrel moves through the interior of a steel tube, and the level of the aforementioned amplification is increased in accordance with a continual decrease in AE sensor signal amplitude, or the level of the aforementioned amplification is decreased in accordance with a continual increase in AE sensor amplitude.

{Detailed Description of the Invention}

### {0001}

(Technological Field of the Invention) The present invention relates to a quality inspection method used during tube expansion. In particular, the invention is a quality inspection method used during tube expansion that is appropriate for inspecting quality aberrations such as cracking or pinholes generated in the joints of long steel tubes, etc., during the expansion of steel tubes.

(Prior Art) In the past, the tube expansion of long tubes formed from steel has been carried out using tube expansion mandrels. As shown in Figure 1, this process involves the insertion of a tube expansion mandrel 20 into one of the open ends of a long tube 30, applying a specified weight P in order to insert the tube expansion mandrel 20 into the long tube 30, and pushing the mandrel across the inner wall of the long tube 30 towards the other end, thus performing tube expansion.

(0003) However, there are cases where quality aberrations such as cracks are produced in steel tubes during the tube expansion process. In particular, with tube expansion in steel tubes having mechanical joints or welded regions produced by welding or diffusion welding, quality aberrations readily occur in welded regions. In order to detect these quality aberrations, non-destructive inspections have been raditionally carried out. For example, ultrasonic defect diagnostic methods have been used wherein ultrasound is made to impinge upon the body to be inspected, and internal defects are found based on differences in reflected waves at end surfaces and defect surfaces. In addition, x-ray defect diagnostic methods have been used in which x-rays are made to impinge upon the body to be inspected, and the transmitted radiation is then used to sensitize film, so that the defects can be detected from the photosensitive image thereupon.

(0004) However, in carrying out these inspection methods, there is the problem that at least part of the detection device must be positioned in the region that is to be inspected, and this creates problems that are exacerbated as the length of the tube increases. In addition, there is the problem these inspection methods cannot be carried out on-site during the tube expansion operation, so they must be carried out after completion of tube expansion, at least in the region that is to be inspected. Specifically, with conventional inspection methods, inspection must be carried out with at least part of the inspection device located in the region to be inspected after completion of tube expansion.

(0005) On the other hand, when installing oil well pipes for drawing oil, etc., out of the ground, technologies are known in which tube expansion is carried out by inserting a steel tube with a comparatively small diameter into the ground, and then inserting a tube expansion mandrel, etc., using high downward compressive force, which thereby reduces equipment installation costs. In order to

inspect expanded steel tubes using this conventional method, it is difficult to situate the inspection device at the outer wall surface of the steel tube, and is also difficult to move the inspection device in the lengthwise direction along the outer wall of the steel tube because the tube has been laid underground. Consequently, it has been necessary to inspect the tube by moving the inspection device long the interior of the steel tube. However, the tube diameter is small even after tube expansion, and the total length of the tube can be as long as several kilometers, so there have been extremely difficult problems with quality aberration inspection over the entire length of a steel tube using conventional methods.

[Problems to be Solved by the Invention] The problem to be solved by the present invention is that of fifering a quality inspection method used at the time of tube expansion, whereby quality aberrations in steel tubes can be evaluated with the inspection device in a stationary condition during the tube expansion process for the steel tube, whereby an occurrence or degree of quality aberration can be determined at a site that is removed from the quality inspection device, and whereby quality aberrations in said steel tube can be detected almost simultaneous to their occurrence.

[Means for Solving the Problems] The gist of the present invention used in order to solve these problems relates to a quality inspection method used during tube expansion wherein an AE sensor for detecting vibrations in a steel tube during tube expansion of said steel tube is situated against the steel tube, and when tube expansion occurs as a tube expansion mandrel moves through the interior of the steel tube, increases in the AE sensor signal amplitude, the number of increases in the AE sensor signal amplitude, or the time over which the increase in AE sensor signal amplitude occurs is detected, and the occurrence of quality aberration in the aforementioned steel tube is determined on the basis of the detected signals.

(0008) By means of the quality inspection method used during tube expansion pertaining to the present invention carried out in this manner, vibrations arising on the interior of a steel tube and on the surface of a steel tube during tube expansion occurring as a tube expansion mandrel passes through the interior of a steel tube are detected by an AE sensor situated on the steel tube, and quality abertation is judged to have occurred when an increase amplitude of the aforementioned AE sensor signal is detected, when the number of increases in amplitude of the aforementioned AE sensor signal reaches a predetermined number, or when the time over which the increase in amplitude of the aforementioned AE sensor signal occurs is foliaged than a predetermined time.

[0009] In addition, as with the invention described in Claim 2, when the degree of quality aberration of the aforementioned steel tube is to be judged based on the magnitude of the increase in AE sensor signal amplitude, the number of increases of AE sensor signal amplitude, the number of increases of AE sensor signal amplitude, the time of the increase in AE sensor signal amplitude, detected at the time when the aforementioned quality aberration is determined, the degree of the quality aberration of the aforementioned steel tube can be determined based on the magnitude of the aforementioned AE sensor signal amplitude, the number of increases in the aforementioned AE sensor signal amplitude, or time over which the amplitude of the AE sensor signal has increased.

(0010) In addition, as pertains to the invention of Claim 3, the AE sensor signal detected during tube expansion is amplified at the time of tube expansions as the tube expansion mandrel moves long the intentor of the siteel tube, and the degree of the aforementioned amplification is increased along with a continual decrease in AE sensor signal amplitude, or the degree of the aforementioned amplification is decreased in a continual or continual increase in AE sensor amplitude.

(0011) With the quality inspection method used during tube expansion described in Claim 3 of the present invention carried out in this manner, the AE sensor signal detected during tube expansion as the tube expansion mandrel moves along the interior of the steel tube is amplified, and as the damping of vibrations generated by the tube as they are conducted to the AE sensor increases, the degree of the aforementioned amplification is uncreased, or as the aforementioned damping decreases, the degree of the aforementioned amplification is decreased. By this means, damping occurring with transmission of the vibrations generated by tube expansion to the AE sensor is compensated for, and quality inspection is carried out based on said corrected AE sensor signal.

(0012) Employing the change in degree of amplification in accordance with a continual increase or continual decrease in output amplitude from the AE sensor means that the change in tube expansion amplitude in a region in which the output amplitude of the relatively stable AE sensor changes continually is taken as a reference. For example, this means that the aforementioned amplification level is not made to follow discontinuous change in amplitude, as with changes in AE sensor signal amplitude produced during the occurrence of aberration. By excluding these regions of discontinuous change in this manner, correction is carried out based on the change in AE sensor signal amplitude, so that even if the AE signal amplitude increases or decreases over time during the observation period over which quality aberrations, etc. are generated, the attenuation can be appropriately corrected for without erroneous correction.

### {0013}

[Embodiments of the Invention] Desirable embodiments of the present invention are described in detail below in reference to the figures. Figure 1 is a schematic constitutional diagram used for schematically presenting the quality inspection method used during tube expansion of steel tubes pertaining to the present invention. A long tube 30 is shown in cross section. Said long tube 30 is a tube produced by welding relatively short steel tubes 30a, 30b, 30c... at weld regions 31a, 31b... In the figure, only three steel tubes are shown, but these tubes continue downwards.

(0014) The tube expansion mandrel 20 has a cylindrical part and a tapered part as shown in the figures, and a load P is applied from behind (upwards in the figure). As the mandrel travels forward (downwards in the figure), the interior wall of the long tube is pressed outwards in a radial direction due to the aforementioned tapered part, thus expanding the aforementioned long tube 30. The AE sensor 10 is situated in contact with the outer wall of the long tube, and the wibrations at said outer surface are converted into signals as the aforementioned tube expansion is taking place. Said signals are output to an inspection device main until 100 to which it is connected.

(0015) Figure 2 is a control block diagram showing an example of the signal processing structure in the quality inspection device implemented in the present invention. In the quality inspection device main unit 100 shown in (a), the AE sensor 10 is connected to an absolute value processor 101, and the absolute value processor 101 is connected to a comparative processor 103. An aberration decision standard value setting part 102 is also connected with the comparative processor 103, and the comparative processor 103 is connected to a notification means 110.

(0016) The aforementioned absolute value processor 101 removes the direct current component of the output signal from the AE sensor 10, and outputs signals that have been converted into absolute values. The aforementioned aberration decision standard value setting part 102 is the part where the aberration decision standard value Th 1 is set, which is the threshold value for determining the size of the signal amplitude from the AE sensor 10. The aberration decision standard value Th 1 should be set at a value that is between the AE sensor signal amplitude when tube expansion is occurring without aberration, and the AE sensor signal amplitude when quality aberrations occur.

(0017) For example, the operator uses a standard value setting knob that is provided in order to set the aberration decision standard value obtained experimentally beforehand in accordance with the type of steel tube that is the subject of tube expansion. In this case, the value is automatically set to a value determined by multiplying the AE sensor signal amplitude As at time ts in the initial stage in which the tube expansion process is initially occurring in said long tube 30 by a constant k<sub>1</sub> that has been determined beforehand (where k<sub>1</sub>>1).

(0018) The aforementioned comparative processor 103 compares the signal input from the absolute value processor 101 with the aforementioned aberration decision standard value Th1, and when the signal from the absolute value processor 101 exceeds the aberration decision standard value Th1, a high-value generation signal is output. When the aforementioned high value generation signal is input into the notification means 110, a quality aberration is judged to have occurred, and an indication of this occurrence is sent to the operator by a tone or display.

(0019) In this manner, when quality inspection is to be carried out by the quality inspection device main unit 100 constituted in the manner shown in (a), the direct current component is taken from the signal from the AE sensor 10, and is rectified to obtain an amplitude. When the signal amplitude from the AE sensor 10 exceeds the aberration decision standard value, a notification is made regarding the occurrence of aberration.

(0020) The quality inspection device unit 100 shown in (b), as can be seen from the figure, has a pulse counting processor 104 between the notification means 110 and the comparative processor 103 constituting the quality inspection device shown in (a) above. The pulse counting processor 104 is connected to the comparative processor 103 and the notification means 110. The number of the aforementioned high value generation signals received from the comparative processor 103 is calculated, and when this number reaches or surpasses the number that has been previously set, a quality aberration occurrence signal is output. In this case, a quality aberration occurrence signal is output when the number of occurrences of high value generation signals is 2 or greater.

(0021) Consequently, when quality inspection is carried out with a quality inspection device unit 100 constituted as indicated in (b), the signal amplitude from the AE sensor 10 exceeds the aberration adecision standard value two or more times, notification of an occurrence of quality aberration is made. (0022) In addition, in this case, the pulse counting processor 104 transmits the number of high value generation signals to the notification means 110 in addition to the aforementioned quality aberration generation signal. The notification means 110 should be constituted in such a manner that notification is made regarding the occurrence of quality aberration, and the degree of quality aberration is made regarding the occurrence of pulsiva aberration, and the degree of quality aberration in accordance with the number of high value generation signals. For example, the device may be constituted so that the number of high value generations itself is made known, but in this case, notification indicating "slight" in regard to the degree of aberration is made when the number is 2 or 3, notification indicating "moderate" is made when the number is 4 or 5, and notification indicating "high? is made when the number is 6 or greater.

(0023) The quality inspection device unit 100 shown in (c) is expanded upon by adding a peak detector 107 to the quality inspection device presented in (a). Output from the absolute value processor 101 and output from the comparative processor 103 is input into the peak value detector 107, and this is linked to the notification means 110. When the aforementioned high value generation signal is output from the aforementioned comparative processor 103, the peak value detector 107 retains the peak value of the output of the absolute value processor 101 at this time, and outputs this value to the aforementioned notification means 110.

(0024) Thus, the notification means 110 reports the degree of quality aberration based on the aforementioned peak value in addition to reporting the occurrence of quality aberration. For example, the magnitude of the peak value itself may be reported, but in this case, notification of a "high", "moderate" or "low" determination is made in regard to the degree of aberration based on the magnitude of the peak value.

(9025) When quality inspection is carried out using the quality inspection device unit 100 constituted as indicated in (c), the signal from the AE sensor 10 is rectified after removing the direct current component, and the amplitude is obtained. When the signal amplitude of the AE sensor 10 exceeds the aberration decision standard value Tb1, sound or display is used in order to present an indication of an occurrence of aberration and the degree of quality aberration based on the peak value of the AE sensor isignal amplitude at the time of occurrence of said quality aberration.

(0026) The quality inspection device unit 100 shown in (d) is a unit in which an envelope detector 100 is also included between the absolute value processor 101 and the comparative processor 103 in the quality inspection device presented in (a), and a pulse width discriminator 108 is also provided between the comparative processor 103 and the notification means 110. The aforementioned envelope detector 106 outputs an envelope signal linking each of the maximum values of the output signals of the absolute value processor 101, and this is transmitted to the comparative processor 103. The comparative processor 103 outputs a high value generation signal to the notification means 110 when the output of the envelope detector 106 is larger than the aforementioned aberation decision standard value Th1. The pulse width discriminator 108 transmits an indication of an aberration occurrence and the length of time for the aforementioned high value generation to the notification means 110 when the time of the aforementioned high value generation signal is longer than a determined time period.

(0027) Thus, the notification means 110 performs notification of a quality aberration occurrence and degree of quality aberration based on the length of the aforementioned high value generation signal. For example, notification may be made as to the length of the aforementioned high value generation signal itself, but in this case, notification is made as to the results of determination based on "high", "moderate" or "low" in regard to the degree of aberration determined based on the length of the aforementioned high value generation signal period.

(0028) When quality inspection is carried out with the quality inspection device unit 100 constituted as shown in (d), the direct current component is removed from the AE sensor 100 signal, and the time for which the envelope intensity of the rectified signal exceeds the aberration decision standard value is calculated. If said time is longer than the determined time period, then sound or display is used in order to make a notification regarding quality aberration and the degree of quality aberration determined based on the time that the envelope intensity exceeded the aberration decision standard value Th1.

(0029) Figure 3 presents a schematic diagram in which the signal waveform for each of the processors is shown in common for Figure 2a, 2b and 2c. Specifically, Figure 3 shows the waveforms outputs at each part of the quality inspection device unit 100 when a quality abertation has occurred at the connection 31b during tube expansion, for the quality inspection system shown in Figure 1, whereas (a) shows the output signal for the AE sensor 10, (b) shows the output signal for the absolute value processor 101, and (c) shows the output value for the comparative processor 103.

[0030] The waveform shown in (a) will be described in sequence. When the tube expansion process is initiated with advancement of the tube expansion mandrel 20 at time to, vibrations are generated via acoustic emission (AE) arising due to plastic deformation, etc., occurring with tube expansion and vibrations are generated due to friction between the long tube 30 and the tube expansion mandrel 10 as a advancement occurs (these vibrations are referred to in combination as "tube expansion vibrations"). When there is no aberration in quality, the tube expansion vibrations give a comparatively weak elastic wave. Consequently, for the period extending from time to, to time 1, during tube expansion of the steel tube 30a, a signal waveform having a comparatively small amplitude is output by the AE sensor 10.

(0031) Next, during the period from time t<sub>1</sub> to time t<sub>2</sub> in which tube expansion of the weld 31a cocurs, said weld region 31a has been welded by mechanical joining, diffusion welding or welding, so its hardness is higher than that of the steel tube 30a. As a result, the progress of the tube expansion mandrel 20 slows, and the aforementioned tube expansion vibrations give vibrations of even weaker amplitude. At this time, the AE sensor 10 outputs a signal waveform for vibrations that are smaller from time t<sub>2</sub> to time t<sub>3</sub>. During the time from t<sub>3</sub> to t<sub>3</sub> in which the steel tube 30b expands, the AE sensor 10 outputs a signal waveform with a comparatively weak amplitude as with the time period from time t<sub>3</sub> to t<sub>3</sub> described above.

[0032] When there is a crack generated during tube expansion of the connection 31b, the energy emanates from the crack, and an elastic wave with a comparatively large amplitude is produced. The tube expansion vibrations that include said elastic waves are detected by the AE sensor 10, and during the period from time t, to time t, a signal waveform with a comparatively large amplitude is output. Subsequently, as shown in the figure, the AE sensor 10 outputs a signal waveform that has a comparatively small amplitude from time t, to time t, during tube expansion of the steel tube 31c as shown in the figure. Then a signal waveform with an even smaller amplitude is output from time t, to time t, during expansion of the next weld region thereof not shown in the figure.

(0033) Meanwhile, the output waveform from the absolute value processor 101 is the absolute value conversion determined after removing the direct current component of the AE sensor output shown in (a), thus producing the waveform shown in (b). In addition, the comparative processor 103 compares the output signal from the aforementioned absolute value processor 101 with the aberration decision standard value TH1 set as described above, and ""Hi" signal is output when the value is larger than said standard value TH1, whereas a "Lo" signal is output when said value is smaller than said standard value.

 $\{0034\}$  Consequently, when the output signal of the absolute value processor 101 shown in (b) is input, the comparative processor 103 outputs the waveform shown in (c). During the time from time to

to time t<sub>3</sub>, the output remains "Lo" because there is no input from the absolute value processor 101 that is higher than the aforementioned abernation decision standard value TH1. Next, because a crack is generated in the time period from time t<sub>3</sub> to t<sub>4</sub>, a signal having an amplitude that is larger than the aforementioned abernation decision standard value TH<sub>4</sub> as shown in (b) is input, and pulses P1 to P3 are output during the time period from time t<sub>5</sub> to t<sub>4</sub> in (c). Subsequently, there is no output that is larger than the aforementioned standard value TH1 during the time period from time t<sub>4</sub> to t<sub>6</sub>, and so the value remains "Lo".

(0035) With the respective quality inspection device units 100 having the constitutions described in (a)-(c)of Figure 2, the following types of processes are carried out based on the output signals shown in (a)-(c) of Figure 3. With the quality inspection device unit 100 shown in Figure 2(a), a "Hi" pulse is output from the comparative processor 103, and an aberration generation signal is output to the notification device 110, so that notification of an occurrence of an aberration is made by the notification means 110.

(0036) With the quality inspection device unit 100 shown in Figure 2(b), the number of pulses output from the comparative processor 103 is 3, and because this corresponds to 2 or more occurrences, notification is made regarding an indication of quality aberration. In addition, notification is also made regarding the degree of quality aberration corresponding to a pulse number of three for the high value signals.

(0037) In the quality inspection device unit 100 shown in Figure 2(c), the peak value detector 107 produces three outputs of "Hi" signals from the comparative processor 103, and so peak values PKI through PK3 of the absolute value processor 101 output are detected during the pulse generation time. Consequently, an abertation occurrence signal and signals representing the peak values PK1 to PK3 are sent to the notification means 110. The notification means 110 then makes notification, via sound or display, of the occurrence of quality abertation, and the degree of the quality abertation corresponding to the aforementioned peak values PK1 through PK3.

[0038] Figure 4 is a diagram that presents a schematic representation of the signal waveforms for each of the processors in Figure 2(d.) Figure 4, specifically, represents the waveform output at each of the parts of the quality inspection device unit 100 when there is a quality abertation at the connection 31b during tube expansion carried out by the quality inspection system presented in Figure 1, whereas (a) represents the output signal of the AE sensor 10, where this waveform is similar to that if Figure 3(a). Here, (b) represents the output signal of the absolute value processor 101, where this waveform similar to that of Figure 3(b), and (c) represents the output waveform of the envelope detector 106.

(0039) The quality inspection device unit 100 having the constitution of (d) in Figure 2 detects quality aberration in the following manner based on the signals presented in Figure 4. The variation in envelope intensity is determined by the pulse width determination part 108 and the comparative processor 103, and when the time during which said envelope intensity is greater than the aforementioned aberration decision standard value Th1 (time over which the comparative processor 103 outputs the aforementioned high value generation signal; represented by T in the figure) is longer than the predetermined time, an aberration generation signal and a signal that transmits the aforementioned time T is sent to the notification means 110. The notification means 110 them makes a notification, via sound or display, as to the occurrence of quality aberration, and the degree of quality aberration corresponding to the aforementioned time period T.

[0040] Figure 5 is a control block diagram showing a processing system example that is different from the steel tube quality inspection device presented in Figures 2(a)-(d). The AE sensor 10 is attached to the aforementioned long tube 30, and surface vibrations from the long tube 30 are converted to signals that are output. The absolute value processor 101 removes the direct current component of the AE sensor 10 output signal, and outputs the absolute value of the resulting signal to the amplification processor 105 and envelope detector 106.

(0041) The amplification processor 105 is the part that amplifies the absolute value processor 101 output, and in order to correct for attenuation of the elastic waves reaching the AE sensor at this time, said level of amplification is made such that it is inversely proportional to said envelope intensity at any give time t, based on the output of the envelope detector 106. Consequently, the level of

amplification at inspection time ts is set at As/At using, as reference, the intensity As of the envelope at time ts during the initial tube expansion period.

{0042} The envelope detector 106 outputs a signal produced by carrying out specified processing on the envelope that links each maximum of the output signals from the absolute value processor 101, and this signal is transmitted to the amplification processor 105. As described in detail below, when no aberrations are being generated during tube expansion of the main steel tube bodies 30a, 30b, 30c..., the envelope is processed taking the amplitude of the AE sensor output as an index of the aforementioned amplification level correction. The result is output to the amplification processor 105. {0043} The aberration decision standard value setting part 102 is the part whereby the aberration decision standard value Th2 is set, which is the threshold value for determining the magnitude of the output signal amplitudes from the amplification processor 105. The aberration decision standard value setting part 102 automatically is set to a value found by multiplying the amplitude As of the output from the envelope detector 106 at time ts during the initial period of the tube expansion process of said long tube 30 by a predetermined constant  $k_2$  (where  $k_2 > 1$ ).

{0044} The aforementioned comparative processor 103 compares the signal input from the amplification processor 105 with the aforementioned aberration decision standard value Th2, and outputs a high value generation signal when the signal of the amplification processor 105 is greater than the aberration decision standard value Th2. The notification means 110 notifies the operator via sound or display as to the occurrence of quality aberration when the aforementioned high value generation signal has been input.

{0045} Figure 6 and Figure 7 are waveform diagrams that give a schematic presentation of the outputs of each of the constitutive processors shown in Figure 5. Specifically, the figures are output waveform diagrams for each of the constitutive processors shown in Figure 5 when cracks occur in the connection 32b along with tube expansion of a long tube 30 having the constitution shown in Figure 1.

{0046} The signal shown in Figure 6(a) is produced by conversion of the vibrations from the long tube into signals by the AE sensor 10. This waveform is the same as the waveform shown in Figure 3(a) and varies similarly. Specifically, an amplitude signal that is comparatively small is output from time to to time to as tube expansion of the steel tube 30a is occurring, whereas an amplitude signal waveform that is smaller than the waveform from time to to time to is output over the time period from time t1 to time t2 during which tube expansion of the weld region 31a occurs.

{0047} Subsequently, over the time period from time t2 to time t3 during which tube expansion of the steel tube 30b occurs, the AE sensor 10 outputs a signal waveform with an amplitude that is comparatively weak, as with the waveform output over the time period from to to t1 above. During the period from time t<sub>3</sub> to t<sub>4</sub> during which cracking occurs during tube expansion in the connection 31b, a signal waveform with a comparatively large amplitude is output. Subsequently, a signal waveform with a comparatively small amplitude is output over the period from time ta to to during which tube expansion of the tube 30c occurs. A signal waveform with a small amplitude is again output over the time period from time t<sub>5</sub> to t<sub>6</sub> during which the subsequent weld region is undergoing tube expansion (not shown in the figure).

{0048} The waveform shown in Figure 6(b) is the output signal from the absolute value processor 101, and results from removing the direct current component of the output signal from the AE sensor 10, and performing absolute value conversion. The waveform represented by the solid line in Figure 6(c) is the output signal from the envelope detector 106, and is produced as a result of processing the envelope from the outputs of the absolute value processor 101 in the manner described below.

(0049) Specifically, the periods from time t<sub>1</sub> to time t<sub>2</sub>, time t<sub>3</sub> to time t<sub>4</sub>, and time t<sub>5</sub> to time t<sub>6</sub>, are times when tube expansion is occurring in weld regions 31a, 31b, 31c... of the long tube, or times when aberrations are occurring. The envelopes for these times produce the waveforms represented by the broken lines in Figure 6(c), but the waveforms represented by said broken lines are not output in these time periods. Rather, values interpolated from the change in envelope intensity at a time before. after, or before and after (represented by the solid lines in the figure) are output as the envelope intensity At for said time points.

(0050) For example, when the difference or ratio of the actual calculated value and the predicted value determined from the change in the envelope using the aforementioned standard exceeds a predetermined range, said predicted value is used instead of said actual value. Thus, the envelope intensities during tube expansion in the weld regions and during quality aberration will be far outside the values predicted from the transition of the envelope intensity during tube expansion of the main body of the steel tube, and so the aforementioned predicted values are used instead of the envelope intensity at these times.

(0051) Figure 7(a) shows the output signal from the amplification processor 105. With regard to the output, the amplification processor 105 amplifies the signal shown in Figure 6(b) that is output by the absolute value processor 101 by a degree of amplification that is inversely proportional to the intensity of the envelope detector output represented by the solid line in Figure 6(c) in order to correct for damping of the elastic waves reaching the AE sensor. As is seen in the figure, the degree of amplification of the signal from the absolute value processor 101 is increased by the amplification processor 105 in accordance with the distance of the AE sensor from the site of tube expansion. An output is thus made after correcting for damping of the elastic waves produced by tube expansion.

(0052) Figure 7(b) shows the output signal from the comparative processor 103. The comparative processor 103 outputs a "Hi" signal when the output of the amplification processor exceeds the aforementioned aberration decision standard value Th2, and thus outputs pulse signals BP to P3 which are high value generation signals during the period from time t3 to t4. The notification means 110 receives said high value generation signals, and uses sound or display to make a notification as to the occurrence of quality aberration.

(0053) In addition, a pulse counting processor is provided between the aforementioned comparative circuit part 103 (sie) and the aforementioned notification means 110, whereby the number of the aforementioned high value generation signals from the comparative processor 103 is counted. This number is then transmitted to the notification means 110. The notification means 110, thus renders notification regarding the occurrence of quality aberration and the degree of quality aberration based on the number of the high value generation signals.

(0054) Meanwhile, a peak value detector is provided that detects the maximum value for the amplification circuit output immediately after the point when the high value generation signal is output from the aforementioned comparative circuit 103. The notification means 110 thus renders notification as to the occurrence of quality aberration, and the degree of quality aberration based on the magnitude of said peak value.

(0055) Figure 8 is an output waveform diagram for each of the processors when cracking occurs during actual tube expansion of the steel tube. Specifically, the figure is an output waveform diagram when quality inspection is actually being carried out according to the present invention using the configuration described in Figure 1 and Figure 2(a). In (a), the high-amplitude output waveforms occurring approximately at times 1<sub>1</sub>, 1<sub>2</sub> and 1<sub>3</sub> are generated due to the occurrence of cracking at these time points.

(0056) As is clear from the figures, when the aforementioned aberration decision standard value Th1 is set to Sx the value of the amplitude As of the AE sensor at time ts in the initial period of tube expansion using the aforementioned aberration decision standard value setting part 102, the comparative processor 103, as shown in (b) generates pulse signals which are the aforementioned high value generation signals, the first being close to time t<sub>1</sub>, the second being close to time t<sub>2</sub> and the third being close to time t<sub>3</sub> and the third being close to time t<sub>3</sub>. Consequently, the notification means sends notification of aberration occurrences at these time points t<sub>1</sub>, t<sub>2</sub> and t<sub>3</sub>.

(0057) The present invention is not restricted by the embodiments described above, and various modifications are possible within a range that does not exceed the scope of the invention. For example, it goes without saying that the steel tube that is the subject of inspection is not restricted to one that has weld regions. The site of attachment of the AE sensor is also not restricted to the side surface of the tube, as the sensor may be attached at the end surface. In the embodiments described above, the tube expansion mandrel had a tapered region, but mandrels are not restricted to this type. For example, a tube expansion mandrel can be used that has expanding diameter rollers present on the

outer surface of the mandrel, so that the internal wall of the steel tube is pressed outwards in a radial direction by means of said expanding diameter rollers.

(0058) On the other hand, regarding setting of the aforementioned aberration decision standard value, modes are not restricted to the process represented in the embodiment, and the value may be set or a value that is between the amplitude of the signal determined when normal tube expansion is occurring and the amplitude of the signal determined when quality aberration occurs. In addition, in the aforementioned embodiment, processing performed by analog signal processors can be carried out by means of digital signal processing. For example, an A/D converter can be provided after the absolute value processor 101 or the amplification processor 105 so that their outputs are converted to digital signals, which are then subjected to digital signal processing for subsequent processes.

Effects of the Invention) By means of the quality inspection method used during tube expansion described in Claim I of the present invention, as tube expansion occurs with movement of the tube expansion mandrel, vibrations are generated at the site of tube expansion. When quality aberrations are generated in the steel tube, the AE sensor signal amplitude increases relative to the amplitude at previous and subsequent time points. By employing this increase, the invention has the ment of allowing determination regarding an occurrence of quality aberration as tube expansion occurs without installing special irradiation devices or drive devices for quality inspection.

(0060) In addition, vibrations generated by tube expansion and by movement of the tube expansion device are transmitted through the steel tube to an AE sensor that is at a location distant from the site where tube expansion is occurring, so that it is possible to perform quality inspection during tube expansion with the inspection device itself fixed at a specific location. In addition, there is also the merit that quality inspection can be carried out as the long steel tube is undergoing expansion. Because the rate of transmission of said vibrations is extremely fast, when quality aberrations such as cracking occur during tube expansion, it is possible to detect the occurrence of quality aberration and the degree of quality aberration nearly simultaneous to its occurrence.

(9061) Moreover, with the quality inspection method used during tube expansion described in Claim 2, in addition to the merits of the quality inspection method described in Claim 1, there is the merit that the degree of quality aberration can be determined simultaneous to the quality aberration with the inspection device itself fixed at a determined location, without requiring the use of special drive devices or irradiation devices for quality inspection.

[0062] Moreover, with the quality inspection method used during tube expansion described in Claim 3, the degree of amplification of the AE sensor is increased in accordance with a continual decrease in AE sensor signal amplitude, or the degree of amplification of the AE sensor signal is decreased in accordance with a continual increase in AE sensor amplitude. By this means, damping of the elastic waves generated due to tube expansion occurring during the time it takes them to reach the AE sensor can be compensated for with high precision, so that it is possible to increase the reliability and accuracy of processing carried out using said AE sensor signal.

(9063) For example, as the tube expansion mandrel becomes increasingly distant from the AE sensor, the decrease in AE sensor signal is compensated for, and thus even with long steel tubes, it is possible to determine the occurrence of quality abertation and the degree of quality abertation with a high level of accuracy. Moreover, because stable determination of the occurrence of quality abertation and the degree of quality abertation is possible with little fluctuation in AE sensor signal amplitude due to change in transmission distance, a quality inspection method for use during tube expansion is provided that increases the reliability of these determinations.

(Brief Describtion of the Figures)

{Figure 1} Schematic constitutional diagram that presents a summary of the quality inspection method during tube expansion of steel tubes pertaining to the present invention.

{Figure 2} Control block diagram showing an example of the signal processing system for the steel tube quality inspection device used in the present invention.

(Figure 3) Diagram giving a schematic presentation of the signal waveforms for each of the processors of Figure 2(a), (b) and (c), where (a) is the waveform diagram of the output signal from the

AE sensor, (b) is the waveform diagram of the output signal from the absolute value processor and (c) is the waveform diagram of the output signal from the comparative processor.

(Figure 4) Diagram giving a schematic presentation of the signal waveforms for each of the processors for Figure 2(d), where (a) is the waveform diagram of the output signal from the AE sensor, (b) is the waveform diagram of the output signal from the absolute value processor and (c) is the waveform diagram of the output signal from the envelope detector.

{Figure 5} Control block diagram showing an example of a processing system other than that of the steel tube quality inspection device presented in Figure 2(a)-(d).

(Figure 6) Waveform diagrams giving a schematic presentation of the outputs of the constitutive processors for the steel tube quality inspection device shown in Figure 5, where (a) is the waveform diagram of the output signal from the AE sensor, (b) is the waveform diagram of the output signal from the absolute value processor and (c) is the waveform diagram of the output signal from the envelope detector.

[Figure 7] Waveform diagrams giving a schematic presentation of the outputs of the constitutive processors for the steel tube quality inspection device shown in Figure 5, where (a) is the waveform diagram of the output signal from the amplification processor and (b) is the waveform diagram of the output signal from the comparative processor.

[Figure 8] Waveform diagrams for the various processors when cracking occurs during actual tube expansion of a steel tube, where (a) is the output waveform diagram from the absolute value processor amplification processor and (b) is the output waveform diagram from the comparative processor.

```
10
         AE sensor
20
        Tube expansion mandrel
30
        Long tube
30a, 30b, 30c... Steel tubes
31a, 31b...Weld regions
100
        Quality inspection device unit
101
        Absolute value processor
        Aberration decision standard value setting part
102
103
        Comparative processor
104
        Pulse calculator
105
        Amplification processor
106
        Envelope detector
107
        Peak value detector
108
        Pulse width determination part
110
        Notification means
[see source for figures]
Figure I
Figure 3
(a)
AE sensor output
Time
Absolute value processor output
Time
```

{Kev}

(c)

Time

Comparative processor output

```
Figure 5
 [see Key above]
 Figure 2
 [see Key above]
 Figure 4
 (a)
 AE sensor output
 Time
 Absolute value processor output
 Time
 (c)
 Envelope detector output
 Time
 Figure 6
 AE sensor output
 Time
(b)
 Absolute value processor output
Time
(c)
Envelope detector output
Time
Figure 7
 (a)
Amplification processor output
Time
(b)
Comparative processor output
Time
Figure 8
Comparative value processor output
Time
(b)
Comparative processor output
Time
Continued from the front page
F Terms (Reference) [see source for codes]
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### AFFIDAVIT OF ACCURACY

I, Kim Stewart, hereby certify that the following is, to the best of my knowledge and belief, true and accurate translations performed by professional translators of the following patents from Japanese to English:

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Sworn to before me this 23rd day of January 2002.

Signature, Notary Public

**.** 

MARIA SUBLIC NOTA SUBLIC In em lete of Texas non 33-22-21

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記品関係を判定した際に検加されるAFセンサ市りの 転幅の大きき、A ヒセンサに5の原始が外入した時間に基づいて 同にはAFセンサ市分の転輪の増大した時間に基づいて 前記解での品質状态の程度を刊度でするようにすれて、前 記入日センサビの原軸の大きとは無づいて前途の 品質異常の程度を削減でき、前記AFセンサ保等の転縮 が増大した回数に基づいて前差開管の品質異常の程度を の増入した時間に基づいて前差開管の品質異常の程度を の増入した時間に基づいて新管の品質異常の程度を同定 するとができ、有しくは、AFセンサ保守の無解 の増入した時間に基づいて新管の品質異常の程度を同定 することができ、

[0010] 実に、結束消まに記載の規則のように、拡 費マンドレルが解答の内部を移動しながら拡管する際に 検出される人モンナの信号を増幅すると共に、AEセ ンナ信号の振幅の速度的な嫌少に応じて海池増幅の度令 を高め、AEセンナの隔層の連続的な増加に応じて前差 増幅の度令を低すさせるようにすると良い。

1001+11 このように行かう水発列の効果項目に記載 の影響やの場所を移動しながら記言する際に機用される人ドセ ンサの信号を増生すると具に、松管により発生する探が さくなると前沿階級の度合を増加させ、高地対域が低下 さと向出力機の度合を増加させ、高地対域が低下 でもと前沿階級の度合を接かさせるように調整するの で、紙管により発生する最初が人とセンサまで使制する ことによって生じる被変が加速され、過程証された人を センサ信号に基づいて高度複数が行とかれる。

【0012】こで、増幅の度合の変化を人とセンサ出 が無償の通機の放映と対し速能を効何側に従ってすかう こととしているのは、拡管により発生する緩動の大きさ が比較的な定しており入目でシテの出力が偏端が越越的に 数化する施位の重複動を表現ですることを要求 構造機合が高端の変化のように非常機能を通過を が出途的な場合をしていては可能機能を避遇を がしたとの意味する。このように非強級変化組分を除いた 人にとその意味する。このように非強級変化組分を除いた 人にとって対常う解析の変化に基づいて制止をすることに より、高質等等が発生して表現を排列の人に目が悪い 等例に関大とは軟少しても高った補重をすることな く。概算を確保に加まする。

[0013]

【0014】転管マンドレル20は国家のようにテーハ 部分と円柱部分とを存し、後方(図面においては上方) から毎度Pを包含れ、前の「図画においては上)」。 毎日たから前面と一へ頭がしまり取入替の内面に下 括方均か方に押し返げて、前記長尺宮30を軽なするも、 のである。 A E モンサ 1 O はお尺等の少増期前に接触する 実施で改置され、前記紙等が行われているときの連外期 前の秘勤を信号に変換するものであり、監視容異本体 1 0 に接続されて振信を出力する。

[00]5] 屋2は、本界に適用される品質配製別 の信息機関展成終売す場所でよりが同かる。 によず高質監視表別本格100においては、AEセンサ 101は投列的処理部101に接続され、異常同次事業 101は投列機理部103に接続され、異常同次事業 定路102も比較処理部103に接続され、其常同次事業 203に当まずを103に接続される。

[0016] 前途総対極数単新101ほれたセンチ10 の出力は9の高級力を取り除き絶対値化した信号を出力 する。何記録有限定法準値定定部102は八ピンサイ 0の信号無線の大きさを判断するための開創である異常 何定基準億日16程度でも動分であり、異常行返基件 値下1は、異常なく就者が行なわれている時ののとセンサ保予経経と高度異常が生生したさる几ピンサ保予 機種との間の値になるように記定されればい、

[0017] 例えば、基準機能でつまみを設けて乾燥対 をの解析の機能にでモゲカ火薬物に得られた長深何度 基準機を操作者が設定するようにしても良いが、ニニで は、身後尺管3のの独管加下を始めた制度操作の場合が 3の心とセンサビリ接偏れ。ほどの設定した機を核 1 (限し、k1>1) を来じた値を目動的に設定するば にする。

[0018] 前記比較処理部103は、総対値処理は、 01か5人力をわる情等を前起異常復返推修工下1と 比較して、総対域処理部101の信分が異常物立返準値 下11を超えた場合に高速を任信分を出力する。第四下 以101に、前記機能を信分が入力されたとかに、高 質異が充生したものと判定し、その符を音声或いせ表 示によって機性表に適知する。

【0019】このようにして、(a) に示すように構成 される品質監視装置本体 100によって品質監視をすれ ば、AEセンサ10の信号は両流分を能力され軽流され 振幅を取得されて、AEセンサ10の信号振幅が異常利 定集準値を超えた場合に異常を4の音が否知される

[0020] (6)に示す結婚監視報報を100日。 様からもからまたに、前足(5)に示す出情能性契例 の構成が良効型解解104次と知事で110との制定へ ルス計数第104分介設されたものである。へルス計数 第104日。比較処理第104及どが知事等110と検 減される。そして、比較処理第104及どが知事等110と検 減される。そして、比較関単第104がで見て高にた何 数を作りの明確を計数し、その関係との対象と につった場合に、高質別条を1659を利力する よびになった場合に、高質別条を1659を利力する。 ときに、品質異常発生信りを出力することにすう。 【0021】従って、(b)に示すように構成される品 質監視装置本体100によって品質監視をすれば、AE センサ100信号は直成分を修正され整成されてその版 概を取得されて、AEセンサ10の信号編編が異常利定

報を取得されて、AEセンサ10の信号振幅が異常利定 基準値を超えた回数が2回以上の場合に、品質異常発生 の質が増加される。

の日か行用される。

【0022】実に、この場合に、バルス月極部104 は、前起は異常発生性等に加えて、延航発生性等の回 数を得か再致110に伝達し、出加手段110日記号異 発発中の形及び高級発生性等の回数に応じた結果異常の 現在を告期するとから開発して有良い。例えば、高 係発生圏社やのものを労働するようにしても良いが、こ つては、2世ないしる国の場合には異常の段後が「約1 である行を、4 同びいしる国の場合には異常の段後が「約2 である行き、4 同びいしる国の場合には異常の段度が「約2 が加ってある手を、6 回以上場合には異常の段度が 「約1」である音を、6 回以上場合には異常の段度が 「独」である音をで加まるようにする。

[0023] (c)に示す最優変異な様々100は、 (a)に示する複数模型第1にもの機能が107を増 起したものである。ビータ機能が307に地対値処 理なり、10円が及び止め転車が107にに地対値処 理なり、70円で収入10円が表が10円がある。 に、70円で収入10円が表が10円が表が20円が表が に、70円では、解説は税量率103から確認商業10 日の明力のビータ値をは付え、確定者が予費110に出 カする

【0024】そして、当知可能110は、結腎系のを 生の行及び前期に一ク値に基づいて高質異常の程度を 知する、例えば、ビーク値の大きさそのものを行動する ようにしても違いが、ここでは、ビーク値の大きさによ り異常の程度を「強」、「中」又は「場」に判別し、そ の制度は表を告知するようによう。

[0025] (c)に示すように構成される品質は関係 対体100によって高質整度やすれば、AFとシャ1 の信号は直接の全部よされ管裏されて機幅を影けされて、 とセンサ10の信号を機が実施を対します。 を超えた場合には、製金化の行き施油質異常が生生したときのAFセンサ信号を確かして、一分的に基づく高管異 の可能をが、原子化技術によって番組されて

1002年 1 (4) に弄す高質監視器度体体1001、(a) に不す高質監視器度の絶対動処理部101と批例 処理部103と四届に包格機構改部106を増減し、比較地質部103と毎期で投110との加工にから本地対策 第108を増減したものである。都定性解検波部10 611、船対機処理部101の形元号の各種大砂を結ぶ 包緒報信1を用力し、比較地理部103に充金15。1 後機理部103に、20裕線後流104の形元が高速型 活用定果単析でト1よりも大きい場に高額化生信号を3 知では110に用力でカールと本権円定部10米に再列 高額を4年に同りの間が新元の開催まりましたともに再列 異常発生の旨及び前記高値発生時間の長さを告知予段! 1 OK G Web 3

10に伝達する、

【0027】そして、告知手録 110日、高質外素の発生の作及研究は発生信が時間の戻さに基づいて高質 異常の程度を分割する。例えば、前記副前発化に分割的 の長さそのものを先加するようにしても良いが、ここで は、総高面積度は2時間の及びよより形なつの度を 「強」、「中」又は「韓」に特別し、その判別制度を 別するようにより

【0028】(4)に向すように構成される品質を提集 基本体100によって新聞電場をすれば、AEとサリ 0のほから運転分を始まされ事成されたは分のは解線 効度が異な物度式管盤を超えた時間を計断し、移時間が 所定の時間よりも長い場合に、異常発化の質をは構築 度が異常期を無断性下りを組えた時間としかくに高質異 第の時度とが、展示を共存されていましたがく、高質異 第の時度とが、展示を共存されていましたが、

【0029】図3は、図2(a)、(b) 及び(c)に 大連する各処理部の付き板形を概念的に示した図であ る。図3は、外格的には、図1に示す、高質電機構成にお いて、故管時に接接第315で高質製剤が発生した場合 高熱性提出資本は1000分部で出力される数形を示 したものであり、(a)はAにセンサ10の出力信号を示 示し、(b)は最早機能2010円の出力信号を示し、 (c)は比較規模距1070円が号を示し、 (c)けば快報運第1030円が号を示し、

【00 00 1 (a) に分す販形を関する。野肉は、 のに数等マンドレル20の歯質によって配着加工が開始 すると、故場行時の配管マンドレル10と長尺管30と の解析による函数級が配置による野生変形等によって生 とないわゆるフコースティックエミンジョン (AE) に よる画数等 (以下、これらをまとめて監管観動とい う、) が発生する、この影響で顕明は出胃気がか生して いない場合には、比較的影・呼性数である。従って、調 言30。の配音中である奇科(10がら)はでの場所に 、AEとセットのは比較からい条組の信号を影形を出

【0031】次に、接合第31。の原質をする時候に、 から12の時間に、議員合第31」は何後ではメリカウェイント、製版核介、溶接等により核介されており、その機 度が解答303よりも高いため配管センドレル20の過 行が高くなり、成配性解析は、促定的収集の対象しなから1 1よりも小さい転機のおり装飾を10月から、解写の を発でする時候12から13までの時間には、高記時刻 10から11までの時間は外が展開とは、高記時刻 10から11までの時間と傾移に、最初時刻 10から11までの時間と傾移に、最初時刻 10から11までの時間と傾移に、最初時刻 10から11までの時間と傾移に、最初時刻

【10 0 3 2】そして、次の複合部31 bの観音中にひび 別れが発生すると、主の戦略によりエネルギーが検査さ れた較的人さな影響の弾性波が生じる。 A E センサ 1 0 は鎮弾性減を含む観音配列を検出して、時刻 1 3 から し 4 の時間には、比較的人まな操縦の指分変形を出力す。 3. 以降、図からわかるようにAEセンサ1のは、網管 31cを拡管する時候14から15の時間には比較的小 版幅の信号波形を、図示しないその次の複合部を拡管する時刻15から16の時間は更に小さい振幅の信号波形 を出力する。

[0033] 一力、松岩電製用紙101の出力規則は、 (a) に示す人とセンサ出力の直流分を除去し絶対例は、 したものであり、(b) に示す例を規則となる。また、 比較製所部1031は、前部絶対値製理部101の出力信 分を前記のように設定された資料可定人単価打日1と比 校して、基基単位111よりも大きいときには「111」 を出力し、基基準値111よりも大きいときには「111」を出力し、基基準値111よりまります。

【0034】従って、比較処理部103は、(b)に示す絶対値処理部101の出力信号が入力されると、

(c) に示す数形を出力する。時刻:0から、19の時間 は、発対極地変形 0 1から16記入料率度基準程 1 1よりも大きな入力がないので出力は「Loi のままで ある。表に、前記のように対象1 3から、4のが簡に及 で放析が発化するので、(b) に示すように、減免で 同じ返降性 11よりも九を大路域の保分が入力まれ、 (c) において時刻:3から、4の時間に、パルスドー から下3を出力する。後いて、時刻:4から、6の時間 は、前尾基準値で111よりも大きな入力がないので、再 び「Loi のままである。

[00:35] 図2:00 (a) ないし(c) の構成を有する 高質型製度が集化 [00:00条件、これらの図3 (d) ないし(c) に示け出力情勢に基づいて、次のように処 整でする、図2 (u) に示す品質管度表数本体100 は、比較処理部 [03:05] 付1] のシルスが出力され たので、契知平度110~異常発生信さを発し、労加平 段110が異常の発生の数単で参加する

【0036】図2(b)に示す品質医規模基本体100 は、比較地理部103から出力されるバルスの同数が3 同であり、2回以上に該当するので品質異落発生の背を 等類する。また、高値発生信号であるバルスの回数の3 同に対定する品質異常の程度を告知するようにしても良い。

【0038】図4は、図2(d)の各処理部の信号波形 を概念的に示した図である「図4は、具体的には、図1 に示す品質監視構成において、仮管時に接続部316で 品質異素が発生した場合の活電と収累用本体1000本で出力される数形を示したものである。(a) 11AE センサ100部1月后号を示し、その数形は図3(a)に 等しい。(b) は絶対値処理部101の出力信号を示 し、その変形は図3(b)に等しい。(c) 1世色路段検 数部106の用力数形を示している。

【0039】関2の(d)の構成を有する品質製製業 本体100は、独4に示す作为に次づき、次のように品 質異常を接加する。比較更新さりの表がから不利可定 部108により図解型域との種様を刊定し、採び解処性 皮が前型異常判定基準値下も1よりも大きい時間(比較 地理部103分組に需値を4に分を出力する時間であ り、関において下で示される。)が所定の時間よりもた り、関において下で示される。)が所定の時間よりもた り、個合に、別事を110に異常を生じまりが過程時

Tを伝える信号を伝送する。告知手段110は、品質異 常の発生の旨及び前記時間Tに対応する品質異常の発鉛

【0042】 仏教翰検教部106は、総対執知票10 1の出力信号の各権人権を結ぶ包籍線に所定の処理をし た保号を用力し、増編処理部105に伝達する。ここで 1は、版に評定するように、国体となる解答30。30 5、30c・・・の監管時であり異示が発生していない 時のAとセンサ用力の振転を再定機能を新すの所能とす るように、仏教線を処理して均偏処理部105に出力す

[0043] 東京神法基準協定選第1021. 州域処理 第1058四川万保予組織の支票を制御するとは 前1058四川万保予組織の支票 東常和支票率額支運第121は接入代第300総管加工 を輸力力別の対象は、少位協議検援第1060加工の 最終点とに呼の近にた係収は2(例し、k2≥1)を 現工生業を目標収集

【0044】前記比較処理部103(比、増幅処理部10 5から入りされる信号を前記判定可定決準値下52と比 校して、増料処理部105の信号が開定判定基準値下6 2を超えた場合に高値優生信号を出力する。借知手段1 10は、前記高値発生信号が入力されたときに、品質異常が発生した音を音声或いけ表示によって操作者に通知 せる。

[0045] 対応及び対7は、以5に元寸を契則核成部の出力を優全的に示した裏部制である。具体的には、対 1に対す構成で取尺管3のの起管を付なって、接合第3 2 bでひび割れが発生した場合における。図5に不す処 乗の4000を添かけ力変形はである。 [0046] 106 (a) に乗り信号は、AEセンサ10

が長尺管の振動を信号化したものである。この被形は、

図3(3)に示す変形と同じであり、全く同様に開発する。即ち、開写の3の回数で名だなが無例のからしまでは比較的小さい単純の信号が出力され、接合部31 a では比較的小さい単純細の信号が出力され、接合部31 a ではしまります。 「日の47] 挟いて、開写30 b の度等を行り時間、日の47] 挟いて、開写30 b の度等を行り時間、こから13 までの時間には、通り割10 t のよりまで、の時間と同様に、A とセンサ10 は比較的強い隔極の信息を振修出力し、接合部31 b の返ぎででありの大きな新知の指令要終を出力する。以降、開写30 c の設等を表彰を10 ありた50 時間1は、比較的大きな新知の指令要終を出力する。以降、開写30 c の設等を表彰を10 から50 時間1は比較的小量能の情景を表彰してある。10 では、日本によりは、日本によりのとなった。10 可能には、比較的大きなある。10 では、日本によりは、日本によりないまりない。10 可能には、20 では、日本によりないました。10 可能には、20 では、日本によりは、日本により、日本によりは、日本により、日本

[00048] 図6 (b) に示す数形は、総対値処理部の 01の出力信号であり、んヒモンサ10回出力信号の直 次分を施止した信号を絶対能によりのである。図6 (c) に実験で示す数形は、包格線検索第106の出力 ほ号であり、総対6短端101の出力の包格線を次の ように数略したものである。

【0049】即5、時刻にから時刻に2、時刻に3から時刻に2、時刻に3から時刻に4及び時刻に5から16の時間に長校等級 校部31は、31ト、31に・・・の地容を行だっている時間とは異常が発生している時間と対象が発生している時間のは2額がは一つて (c)に確認で示す変形とが10世ず、その前、後又は後で の時間のとは発験で示す変形を10世ず、その前、後又は後で 示す。)を終当時期の2番階強度の変化から新聞した地(四十年)

100501 例以は、前点比較の必数数の無料から求め たり額的と実際の計劃があるが表とは比が再定の範囲を想 えた場合には、該実制がのほりまに無子制能をもおいる まりにすればない。このようにすれば、核底部の起答時 以び語質無空を自動の心器等が強度に同体の期等の現容時 の回転解決度の単位から下側される能を大きく失れるの で、これらの時刻の包器保険度のほわりに前途と構動が を用しなる。

【0051】図7 (a) は、増幅処理部105の出力は、 等である。この出力は、増幅処理部105が、AEセン サビい、発性表の域長を推計するために、図6 (c) に 実験で示する路線検接部出力の効度に戻し得する特础度 で、絶対値处理部 0 1 か引力する図6 (b) に示すに 号を相信した規模である。図からもかかるように、開稿 処理部 1 0 5 は後が終り割割り 10 のほうを指揮するよ 合を、拡発中の単位からAドセンサの単端が維れるに応 して高か、数質による発性数の検責を適能に補正して出 カオカ

【0053】更に、前記比較國務部103と前記的如手 取110との間に、バルス計数処理配を設け、比較処理 が103からの配金付整性に対して 同数を告知手段110に位え、告知手段110は高質異 家発生の背及び動材を生活がの回数に応じた高質異常の 程度を告知するようにしても、とい

【0054】一方、前記比較回路103からの高値発生 ほ号が出力されたときに、その直後の増延回路出力の株 水値を検出し、その値を9知平段に伝えるビーク値検出 部を設け、告知手段110は高質異常発生の音及び長ヒ 一ク値の大きさに応じた高質異常の程度を告知するよう にしてもよい。

[0055] 図れは、解答を実際に発音してひびれれが 発生したときの外処理部の出力波形別である。 4年的に 、 知1 及び図2 (a) に記録の構成によって、 4 条列 による品質監視を実際に行なった場合の出力波形別であ る。 (a) において、対抗1 i 前後、時刻1 2 前後、時刻1 3 前後に発する人を実際の出力波形は、から の時刻に、ひび別れが発生したために生じたものであ

【0056】関からもおかるように、前記異常和法基件 認政定部102が、前記異常和定法単値下11を秘密制 別の時候は、にはける人民センサの結構しなり活動 に設定すると、比較処理部103は(b)にポリように 前記訟が保存しなりあるかり入りを軽減110円を生する。後 って、判断を貸110に2回、時刻13に3回発生する。後 って、予知手段110によれらの時候11、12又は 13に異常化生の特を含むする。

[0057] 本処別は、簡記した実験の形態に作り料定 されるためではな、本製印の場合を微しない。範囲で 棒々の改変が可能である。何之は、監視対象となる舞符 は接合総を有するものはあれない。とは、言うまでも ない。AEセンツの取得は彼は新物での側に限られて、 締結に取り付けてもよい。また、前次定義の形態では、 総管シンドレルをと、小なから行ると感管シンドレルと

したが、これに限られるわけではなく、例えば、マンド レルの外側面に拡径ローラを有し、減拡径ローラにより 鋼管内壁を半径方向外方に押し広げて拡管を行なう構成 の転管マンドレルとしても良い。

【0058】 方、前記異常判定基準値の設定について も実施の形態で例示した処理に限られず、異常なく拡管 が行なわれている時の判定対象となる信号の振幅と品質 異常が発生した時の判定対象となる信号の振幅との間の 値になるように設定すればよい。更に、前紀実験の形態 において、アナログ信号処理により行なっている処理 を、デジタル信号処理により行なうようにしてもよい。 例えば、絶対循処即然101歳いは地域処理が105の 後にA/I)コンバータを設けてその出力をデジタル信号 に変換し、以降の処理をデジタル信号処理により行なう ようにしてもよい。

#### [0059]

【発明の効果】本発明の請求項1に記載の総管時の品質 監視方法によれば、拡管マンドレルが移動して拡管をす るときには、常に拡管部位で振動が発生しており、鋼管 に品質異常が発生した際には、AEセンサ信号振幅がそ の前後の時刻の板幅よりも大きくなることを利用したも のであり、品質監視のために特別に励振装置、照射装置 等を設けることなく拡管時の品質異常の発生を判定する ことが可能であるという効果を有する。

【0060】また、かかる拡管装置が移動及び拡管する ときに発生する振動は、拡管している部位から離れた位 置にあるAビセンサまで顕管を伝輸して届くので、監視 装置全体が一定の場所に静止した状態で拡管時の品質監 視を行なうことが可能であり、かつ、長尺の鋼管の拡管 時の品質監視が可能であるという効果を有する。更に、 該援動が伝搬する速度は非常に速いので、拡管によって 例えばひび割れ等の品質異常が発生したときには、発生 とほぼ同時に品質異常の発生又はその品質異常の程度を 検出することが可能である。

【0061】更に、請求項2に記載の証管時の品質監視 方法によれば、請求項1に記載の品質監視方法の効果に 加えて、品質監視のために特別に助振装置、照射装置等 を設ける必要がなく、監視装置全体が一定の場所に静止 した状態で、品質異常の発生とほぼ間時に、品質異常の 程度を判定することができるという効果を奏する。

【0062】また、請求項3に示す拡発時の品質監視方 法によれば、A E センサ信号の振幅の連続的な減少に応 じてAEセンサの増幅の度合を高め、AEセンサの転輪 の連続的な増加に応じてAEセンサ結号の増幅の度合を 低下させるようにしたので、拡管によって生じる発性波 がAEセンサに届くまでの減衰を高い措度で補正するこ とができ、該AEセンリ信号を用いて行なう処理の確実 性及び信頼性を高めることができるという効果を有す。 3

【0063】例えば、拡管マンドレルがAEセンサから

離れている場合にはAEセンサ信号の低下が補正される ので、より長尺の鋼管においても確実性の高い品質異常 の発生の判定及び品質異常の程度の判定が可能になる。 また、伝搬距離の変動によるAEセンサ信号振幅の変動 が小さくなり、品質異常の発生の判定及び品質異常の程 度の判定の感度が安定するので、これらの判定の信頼性 を高めた拡管時の品質監視方法が提供されることにな

#### 【図前の簡単な19円】

【図1】本発明に係る鋼管の拡管時の品質監視方法の概 念を説明するために示した概略構成図である。

【図2】本発明に適用される創作品質監視装置の信号処 理構成例を示す制御プロック図である。

【図3】図2 (a)、(b) 及び(c) に共通する各処 理部の信号波形を概念的に示した図であり、(a) It A Eセンサの出力信号、(b)は絶対値処理部の出力信 号、(c)は比較処理部の出力信号を示す波形図であ 3

【図4】図2(d)の各処理部の信号被形を概念的に示 した図であり、(a) はAEセンサの出力信号、(b) は絶対値処理部の出力信号、(c)は包絡線検波部の出 力信号を示す数形図である

【図5】図2 (a) ~ (d) に示した網管品質監視装置 以外の処理構成例を示す制御プロック図である。

【図6】図5に示す鋼管品質監視装置における各処理構 成部の出力を概念的に示した被形図であり、(a) tiA Eセンサの出力信号、(b) は絶対銃処理部の出力信 号、(e)は包絡線検波部の出力信号を示す波形図であ

る. 【図7】図5に示す鋼管品質監視装置における各処理構 成部の出力を概念的に示した波形図であり、(a)は増 幅処理部の出力信号、(b) は比較処理部の出力信号を 示す波形図である。

【図8】鋼管を実際に拡管してひび割れが発生したとき の各処理部の出力波形図であり、(a)は絶対値処理部 の出力裁形図、(b) は比較処理部の出力裁形図であ

### 【符号の数刊】 10 AEセンサ 30 ほ尺管

20 拡管マンドレル

30m、30m、30m、・・・ 知管

31 a. 31 b. · · · 接合紙 100 品質監視装置本体

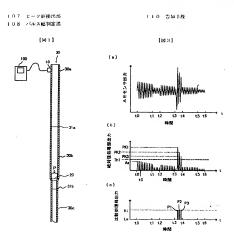
101 絶対値処理部

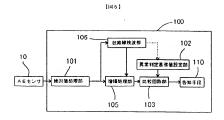
102 異常判定基準值設定部

103 比较処理部 104 ハルス計数部

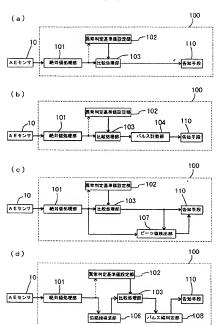
1.0.5 四極級中部

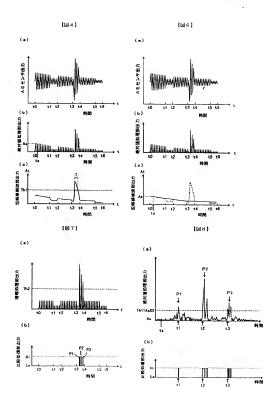
106 包箱線接波部











### フロントページの続き

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Continued on last page

(54) {Title of the Invention} Quality Inspection Method for Use During Tube Expansion

### (57) {Summary}

{Problem}

To offer a quality inspection method for expanded tubes whereby the occurrence of quality aberration or the degree of quality aberration can be determined at the time of expansion of the steel tube, and whereby remote observation is possible.

(Solution) An AE sensor 10, which detects steel tube vibrations during tube expansion occurring as a tube expansion mandrel 20 moves through the interior of a steel tube 30, is situated against the steel tube. Increases in the AE sensor signal amplitude, the number of increases in the AE sensor signal amplitude or the time over which the increase in AE sensor signal amplitude occurs is detected, and the occurrence of quality aberration or the degree of quality aberration in the aforementioned steel tube is determined on the basis of the detected signals.

[see source for diagram]

(Scope of Patent Claims)

[Claim 1] A quality inspection method for use during tube expansion, characterized in that an AE sensor for detecting vibrations in a steel tube during tube expansion of said steel tube is situated against the steel tube, and when tube expansion occurs as a tube expansion mandrel moves through the interior of the steel tube, increases in the AE sensor signal amplitude, the number of increases in the AE sensor signal amplitude or the time over which the increase in AE sensor signal amplitude occurs is detected, and the occurrence of quality aberration in the aforementioned steel tube is determined on the basis of the detected signals.

(Claim 2) The quality inspection method for use during tube expansion according to Claim 1, characterized in that the degree of the quality aberration in the steel tube is determined based on the magnitude of the AE sensor signal amplitude, the number of increases in AE sensor signal amplitude or the time of increase in AE sensor signal amplitude.

(Claim 3) The quality inspection method for use during tube expansion described in Claim 1 or 2, characterized in that the AE sensor signal that is detected during tube expansion is amplified as a tube expansion mandrel moves through the interior of a steel tube, and the level of the aforementioned amplification is increased in accordance with a continual decrease in AE sensor signal amplitude, or the level of the aforementioned amplification is decreased in accordance with a continual increase in AE sensor amplitude.

{Detailed Description of the Invention}

{0001

(Technological Field of the Invention): The present invention relates to a quality inspection method used during tube expansion. In particular, the invention is a quality inspection method used during tube expansion that is appropriate for inspecting quality aberrations such as cracking or pinholes generated in the joints of long steel tubes, etc., during the expansion of steel tubes. (0002)

[Prior Art] In the past, the tube expansion of long tubes formed from steel has been carried out using tube expansion mandrels. As shown in Figure 1, this process involves the insertion of a tube expansion mandrel 20 into one of the open ends of a long tube 30, applying a specified weight P in order to insert the tube expansion mandrel 20 into the long tube 30, and pushing the mandrel across the inner wall of the long tube 30 towards the other end, thus performing tube expansion.

(0003) However, there are cases where quality abernations such as cracks are produced in seel tubes during the tube expansion process. In particular, with tube expansion in steel tubes having mechanical joints or welded regions produced by welding or diffusion welding, quality abernations readily occur in welded regions. In order to detect these quality abernations, non-destructive inspections have been traditionally carried out. For example, ultrasonic defect diagnostic methods have been used wherein ultrasound is made to impinge upon the body to be inspected, and internal defects are found based on differences in reflected waves at end surfaces and defect surfaces. In addition, x-ray defect diagnostic methods have been used in which x-rays are made to impinge upon the body to be inspected, and the transmitted radiation is then used to sensitize film, so that the defects can be detected from the photosensitive image thereupon.

(0004) However, in carrying out these inspection methods, there is the problem that at least part of the detection device must be positioned in the region that is to be inspected, and this creates problems that are exacerbated as the length of the tube increases. In addition, there is the problem these inspection methods cannot be carried out on-site during the tube expansion operation, so they must be carried out after completion of tube expansion, at least in the region to that is to be inspected. Specifically, with conventional inspection methods, inspection must be carried out with at least part of the inspection device located in the region to be inspected after completion of tube expansion.

(0005) On the other hand, when installing oil well pipes for drawing oil, etc., out of the ground, technologies are known in which tube expansion is carried out by inserting a steel tube with a comparatively small diameter into the ground, and then inserting a tube expansion mandrel, etc., using high downward compressive force, which thereby reduces equipment installation costs. In order to

inspect expanded steel tubes using this conventional method, it is difficult to situate the inspection device at the outer wall surface of the steel tube, and is also difficult to move the inspection device in the lengthwise direction along the outer wall of the steel tube because the tube has been laid underground. Consequently, it has been necessary to inspect the tube by moving the inspection device long the interior of the steel tube. However, the tube diameter is small even after tube expansion, and the total length of the tube can be as long as several kilometers, so there have been extremely difficult problems with quality aberration inspection over the entire length of a steel tube using conventional methods.

[Problems to be Solved by the Invention] The problem to be solved by the present invention is that of fefring a quality inspection method used at the time of tube expansion, whereby quality aberrations in steel tubes can be evaluated with the inspection device in a stationary condition during the tube expansion process for the steel tube, whereby an occurrence or degree of quality aberration can be determined at a site that is removed from the quality inspection device, and whereby quality aberrations in said steel tube can be detected almost simultaneous to their occurrence. 1000071

(Means for Solving the Problems) The gist of the present invention used in order to solve these problems relates to a quality inspection method used during tube expansion wherein an AE sensor for detecting vibrations in a steel tube during tube expansion of said steel tube is situated against the steel tube, and when tube expansion occurs as a tube expansion mandrel moves through the interior of the steel tube, increases in the AE sensor signal amplitude, the number of increases in the AE sensor signal amplitude, or the time over which the increase in AE sensor signal amplitude occurs is detected, and the occurrence of quality aberration in the aforementioned steel tube is determined on the basis of the detected signals.

(0008) By means of the quality inspection method used during tube expansion pertaining to the present invention carried out in this manner, vibrations arising on the interior of a steel tube and on the surface of a steel tube during tube expansion occurring as a tube expansion mandre passes through the interior of a steel tube are detected by an AE sensor situated on the steel tube, and quality abertation is judged to have occurred when an increase amplitude of the aforementioned AE sensor signal is detected, when the number of increases in amplitude of the aforementioned AE sensor signal reaches a predetermined number, or when the time over which the increase in amplitude of the aforementioned AE sensor signal occurs is longer than a predetermined time.

[0009] In addition, as with the invention described in Claim 2, when the degree of quality aberration of the aforementioned steel tube is to be judged based on the magnitude of the increase in AE sensor signal amplitude, the number of increases of AE sensor signal amplitude, the time of the increase in AE sensor signal amplitude, detected at the time when the aforementioned quality aberration is determined, the degree of the quality aberration of the aforementioned steel tube can be determined based on the magnitude of the aforementioned AE sensor signal amplitude, the number of increases in the aforementioned AE sensor signal amplitude, the number of increases in the aforementioned AE sensor signal as increased.

(0010) In addition, as pertains to the invention of Claim 3, the AE sensor signal detected during tube expansion is amplified at the time of tube expansion as the tube expansion mander inoves long the interior of the steel tube, and the degree of the aforementioned amplification is increased along with a continual decrease in AE sensor signal amplitude, or the degree of the aforementioned amplification is decreased in a continual increase in AE sensor amplitude.

(0011) With the quality inspection method used during tube expansion described in Claim 3 of the present invention carried out in this manner, the AE sensor signal detected during tube expansion as the tube expansion mandrel moves along the interior of the steel tube is amplified, and as the damping of vibrations generated by the tube as they are conducted to the AE sensor increases, the degree of the aforementioned amplification is increased, or as the aforementioned damping decreases, the degree of the aforementioned amplification is decreased. By this means, damping occurring with transmission of the vibrations generated by tube expansion to the AE sensor is compensated for, and quality inspection is carried out based on said corrected AE sensor signal.

(0012) Employing the change in degree of amplification in accordance with a continual increase or continual decrease in output amplitude from the AE sensor means that the change in tube expansion amplitude in a region in which the output amplitude of the relatively stable AE sensor changes continually is taken as a reference. For example, this means that the aforementioned amplification level is not made to follow discontinuous change in amplitude, as with changes in AE sensor signal amplitude produced during the occurrence of aberration. By excluding these regions of discontinuous change in this manner, correction is carried out based on the change in AE sensor signal amplitude, so that even if the AE signal amplitude increases or decreases over time during the observation period over which quality aberrations, etc. are generated, the attenuation can be appropriately corrected for without erroneous correction.

### (0013)

(Embodiments of the Invention) Desirable embodiments of the present invention are described in detail below in reference to the figures. Figure 1 is a schematic constitutional diagram used for schematically presenting the quality inspection method used during tube expansion of steel tubes pertaining to the present invention. A long tube 30 is shown in cross section. Said long tube 30 is a tube produced by welding relatively short steel tubes 30a, 30b, 30c... at weld regions 31a, 31b... In the figure, only three steel tubes are shown, but these tubes continue downwards.

[0014] The tube expansion mandrel 20 has a cylindrical part and a tapered part as shown in the figures, and a load P is applied from behind (upwards in the figure). As the mandrel travels forward (downwards in the figure), the interior wall of the long tube is pressed outwards in a radial direction due to the aforementioned tapered part, thus expanding the aforementioned long tube 30. The AE sensor 10 is situated in contact with the outer wall of the long tube, and the vibrations at said outer surface are converted into signals as the aforementioned tube expansion is taking place. Said signals are output to an inspection device main until 1900 to which it is connected.

(0015) Figure 2 is a control block diagram showing an example of the signal processing structure in the quality inspection device implemented in the present invention. In the quality inspection device main unit 100 shown in (a), the AE sensor 101 is connected to an absolute value processor 101, and the absolute value processor 101 is connected to a comparative processor 103. An aberration decision standard value setting part 102 is also connected with the comparative processor 103, and the comparative processor 103 is connected to a notification means 110.

(0016) The aforementioned absolute value processor 101 removes the direct current component of the output signal from the AE sensor 10, and outputs signals that have been converted into absolute values. The aforementioned aberration decision standard value setting part 102 is the part where the absence of the signal amplitude from the AE sensor 10. The aberration decision standard value Th is set, which is the threshold value for determining the size of the signal amplitude from the AE sensor ion. The aberration decision standard value Th is hould be set at a value that is between the AE sensor signal amplitude when tuble expansion is occurring without aberration, and the AE sensor signal amplitude when quality aberrations occur.

(0017) For example, the operator uses a standard value setting knob that is provided in order to set the aberration decision standard value obtained experimentally beforehand in accordance with the type of steel thus that is the subject of tube expansion. In this case, the value is automatically set to a value determined by multiplying the AE sensor signal amplitude As at time ts in the initial stage in which the tube expansion process is initially occurring in said long tube 30 by a constant k<sub>1</sub> that has been determined beforehand (where k<sub>1</sub>> 1).

(0018) The aforementioned comparative processor 103 compares the signal input from the absolute value processor 101 with the aforementioned aberration decision standard value Th1, and when the signal from the absolute value processor 101 exceeds the aberration decision standard value Th1, a high-value generation signal is output. When the aforementioned high value generation signal is imput into the notification means 110, a quality aberration is judged to have occurred, and an indication of this occurrence is sent to the operator by a tone or display.

(0019) In this manner, when quality inspection is to be carried out by the quality inspection device main unit 100 constituted in the manner shown in (a), the direct current component is taken from the signal from the AE sensor 10. and is rectified to obtain an amplitude. When the signal amplitude from the AE sensor 10 exceeds the aberration decision standard value, a notification is made regarding the occurrence of aberration.

(0020) The quality inspection device unit 100 shown in (b), as can be seen from the figure, has a pulse counting processor 104 between the notification means 110 and the comparative processor 103 constituting the quality inspection device shown in (a) above. The pulse counting processor 104 is connected to the comparative processor 103 and the notification means 110. The number of the aforementioned high value generation signals received from the comparative processor 103 is calculated, and when this number reaches or surpasses the number that has been previously set, a quality aberration occurrence signal is output. In this case, a quality aberration occurrence signal is output when the number of occurrences of high value generation signals is 2 or greater.

[0021] Consequently, when quality inspection is earned out with a quality inspection device unit 100 constituted as indicated in (b), the signal amplitude From the AE sensor 10 is removed and rectified, and its amplitude is obtained. When the signal amplitude from the AE sensor 10 exceeds the aberration decision standard value two or more times, notification of an occurrence of quality aberration is made. [0022] In addition, in this case, the pulse counting processor 104 transmits the number of high value generation signals to the notification means 110 in addition to the aforementioned quality aberration generation signal. The notification means 110 should be constituted in such a manner that notification is made regarding the occurrence of quality aberration, and the degree of quality aberration is accordance with the number of high value generations signals. For example, the device may be constituted so that the number of high value generations itself is made known, but in this case, notification indicating "slight" in regard to the degree of aberration is made when the number is 2 or 3, notification indicating "moderate" is made when the number is 4 or 5, and notification indicating "flight" is regard to the degree of aberration is made when the number is 6 or greater.

(0023) The quality inspection device unit 100 shown in (c) is expanded upon by adding a peak detector 107 to the quality inspection device presented in (a). Output from the absolute value processor 101 and output from the comparative processor 103 is input into the peak value detector 107, and this is linked to the notification means 110. When the aforementioned high value generation signal is output from the aforementioned comparative processor 103, the peak value detector 107 retains the peak value of the output of the absolute value processor 101 at this time, and outputs this value to the aforementioned notification means 110.

(0024) Thus, the notification means 110 reports the degree of quality aberration based on the aforementioned peak value in addition to reporting the occurrence of quality aberration. For example, the magnitude of the peak value itself may be reported, but in this case, notification of a "hight", "moderate" or "low" determination is made in regard to the degree of aberration based on the magnitude of the neak value.

(0025) When quality inspection is carried out using the quality inspection device unit 100 constituted as indicated in (c), the signal from the AE sensor 10 is rectified after removing the direct current component, and the amplitude is obtained. When the signal amplitude of the AE sensor 10 exceeds the aberration decision standard value Th1, sound or display is used in order to present an indication of an occurrence of aberration and the degree of quality aberration based on the peak value of the AE sensor isgnal amplitude at the time of occurrence of said quality aberration.

(0026) The quality inspection device unit 100 shown in (d) is a unit in which an envelope detector 100 is also included between the absolute value processor 101 and the comparative processor 103 in the quality inspection device presented in (a), and a pulse width discriminator 108 is also provided between the comparative processor 103 and the notification means 110. The aforementioned envelope detector 106 outputs at envelope signal linking each of the maximum values of the output signals of the absolute value processor 101, and this is transmitted to the comparative processor 103 outputs a high value generation signal to the notification means 110 when the output of the envelope detector 106 is larger than the aforementioned aberation decision standard value Th1. The pulse width discriminator 108 transmits an indication of an aberration occurrence and the length of time for the aforementioned high value generation to the notification means 110 when the time of the aforementioned high value generation to the notification means 110 when the time of the aforementioned high value generation to the notification means 110 when

(0027) Thus, the notification means 110 performs notification of a quality aberration occurrence and degree of quality aberration based on the length of the aforementioned high value generation signal itself, but in this case, notification is made as to the results of determination based on "high", "moderate" or "low" in regard to the degree of aberration determined based on the length of the aforementioned high value generation signal period.

(0028) When quality inspection is carried out with the quality inspection device unit 100 constituted as shown in (d), the direct current component is removed from the AE sensor 100 signal, and the time for which the envelope intensity of the rectified signal exceeds the aberration decision standard value is calculated. If said time is longer than the determined time period, then sound or display is used in order to make a notification regarding quality aberration and the degree of quality aberration determined based on the time that the envelope intensity exceeded the aberration decision standard value Th1.

(0029) Figure 3 presents a schematic diagram in which the signal waveform for each of the processors is shown in common for Figure 2a, 2b and 2c. Specifically, Figure 3 shows the waveforms outputs at each part of the quality inspection device unit 100 when a quality abertation has occurred at the connection 31b during tube expansion, for the quality inspection system shown in Figure 1, whereas (a) shows the output signal for the AE sensor 10, (b) shows the output signal for the absolute value processor 101, and (c) shows the output value for the comparative processor 103.

(0030) The waveform shown in (a) will be described in sequence. When the tube expansion process is initiated with advancement of the tube expansion mander! 20 at time to, vibrations are generated via acoustic emission (AE) arising due to plastic deformation, etc., occurring with tube expansion and vibrations are generated due to friction between the long tube 30 and the tube expansion mander! 10 as advancement occurs (these vibrations are referred to in combination as "tube expansion vibrations"). When there is no aberration in quality, the tube expansion vibrations give a comparatively weak elastic wave. Consequently, for the period extending from time to to time to during tube expansion of the steel tube 30a, a signal waveform having a comparatively small amplitude is output by the AE estasor 10.

[0031] Next, during the period from time t<sub>1</sub> to time t<sub>2</sub> in which tube expansion of the weld 31a occurs, said weld region 31a has been welded by mechanical joining, diffusion welding or welding, so its hardness is higher than that of the steel tube 30a. As a result, the progress of the tube expansion mandrel 20 slows, and the aforementioned tube expansion vibrations give vibrations of even weaker amplitude. At this time, the AE sensor 10 outputs a signal waveform for vibrations that are smaller from time t<sub>2</sub> to time t<sub>3</sub>. During the time from t<sub>3</sub> to t<sub>3</sub> in which the steel tube 30b expands, the AE sensor 10 outputs a signal waveform with a comparatively weak amplitude as with the time period from time t<sub>3</sub> to t<sub>3</sub> described above.

[0032] When there is a crack generated during tube expansion of the connection 31b, the energy emanates from the crack, and an elastic wave with a comparatively large amplitude is produced. The tube expansion vibrations that include said elastic waves are detected by the AE sensor 10, and during the period from time t, to time t, a signal waveform with a comparatively large amplitude is output. Subsequently, as shown in the figure, the AE sensor 10 outputs a signal waveform that has a comparatively small amplitude from time t, to time t, during tube expansion of the steel tube 31c as shown in the figure. Then a signal waveform with an even smaller amplitude is output from time t, to time t, during expansion of the next weld region thereof not shown in the figure.

(0033) Meanwhile, the output waveform from the absolute value processor 101 is the absolute value conversion determined after removing the direct current component of the AE sensor output shown in (a), thus producing the waveform shown in (b). In addition, the comparative processor 103 compares the output signal from the aforementioned absolute value processor 101 with the aberration decision standard value THI set as described above, and a "Hi" signal is output when the value is larger than said standard value THI, whereas a "Lo" signal is output when said value is smaller than said standard value.

[0034] Consequently, when the output signal of the absolute value processor 101 shown in (b) is input, the comparative processor 103 outputs the waveform shown in (c). During the time from time to

to time t<sub>3</sub>, the output remains "Lo" because there is no input from the absolute value processor 101 that is higher than the aforementioned abernation decision standard value THI. Next, because a crack is generated in the time period from time t<sub>1</sub> to t<sub>4</sub>, a signal having an amplitude that is larger than the aforementioned abernation decision standard value THI, as shown in (b) is input, and pulses PI to P3 are output during the time period from time t<sub>1</sub> to t<sub>4</sub> in (c). Subsequently, there is no output that is larger than the aforementioned standard value THI during the time period from time t<sub>4</sub> to t<sub>4</sub>, and so the value remains "Lo".

[0035] With the respective quality inspection device units 100 having the constitutions described in (a)-(c) of Figure 2, the following types of processes are carried out based on the output signals shown in (a)-(c) of Figure 3. With the quality inspection device unit 100 shown in Figure 2(a), a "H" pulse is output from the comparative processor 103, and an aberration generation signal is output to the notification device 110, so that notification of an occurrence of an aberration is made by the notification means 110.

(0036) With the quality inspection device unit 100 shown in Figure 2(b), the number of pulses output from the comparative processor 103 is 3, and because this corresponds to 2 or more occurrences, notification is made regarding an indication of quality abertation. In addition, notification is also made regarding the degree of quality abertation corresponding to a pulse number of three for the high value signals.

(Ö337) In the quality inspection device unit 100 shown in Figure 2(c), the peak value detector 107 produces three outputs of "Hir" signals from the comparative processor 103, and so peak values PKI through PKS of the absolute value processor 101 output are detected during the pulse generation time. Consequently, an abernation occurrence signal and signals representing the peak values PKI to PK3 are sent to the notification means 110. The notification means 110 then makes notification, via sound or display, of the occurrence of quality abernation, and the degree of the quality abernation corresponding to the aforementioned peak values PKI through PK3.

(9038) Figure 4 is a diagram that presents a schematic representation of the signal waveforms for each of the processors in Figure 2(d). Figure 4, specifically, represents the waveform output at each of the parts of the quality inspection device unit 100 when there is a quality aberration at the connection 31b during tube expansion carried out by the quality inspection system presented in Figure 1, whereas (1) represents the output signal of the AE sensor 10, where this waveform is similar to that if Figure 3(a). Here, (b) represents the output signal of the absolute value processor 101, where this waveform is similar to that of Figure 3(b), and (c) represents the output waveform of the envelope detector 106.

(0039) The quality inspection device unit 100 having the constitution of (d) in Figure 2 detects quality aberration in the following manner based on the signals presented in Figure 4. The variation in envelope intensity is determined by the pulse width determination part 108 and the comparative processor 103, and when the time during which said envelope intensity is greater than the aforementioned aberration decision standard value Th1 (time over which the comparative processor 103 outputs the aforementioned high value generation signal; represented by T in the figure) is longer than the predetermined time, an aberration generation signal and a signal that transmits the aforementioned time T is sent to the notification means 110. The notification means 110 then makes a notification, via sound or display, as to the occurrence of quality aberration, and the degree of quality aberration corresponding to the aforementioned time period T.

(0040) Figure 5 is a control block diagram showing a processing system example that is different from the steel tube quality inspection device presented in Figures 2(a)-(d). The AE sensor 10 is attached to the aforementioned long tube 30, and surface vibrations from the long tube 30 are converted to signals that are output. The absolute value processor 101 removes the direct current component of the AE sensor 10 output signal, and outputs the absolute value of the resulting signal to the amplification processor 105 and envelope detector 106.

[0041] The amplification processor 105 is the part that amplifies the absolute value processor 101 output, and in order to correct for attenuation of the elastic waves reaching the AE sensor at this time, said level of amplification is made such that it is inversely proportional to said envelope intensity at any give time t, based on the output of the envelope detector 106. Consequently, the level of

amplification at inspection time ts is set at As/At using, as reference, the intensity As of the envelope at time ts during the initial tube expansion period.

(0042) The envelope detector 106 outputs a signal produced by carrying out specified processing on the envelope that links each maximum of the output signals from the absolute value processor 101, and this signal is transmitted to the amplification processor 105. As described in detail below, when no aberrations are being generated during tube expansion of the main steel tube bodies 30a, 30b, 00c., the envelope is processed taking the amplitude of the AE sensor output as an index of the aforementioned amplification level correction. The result is output to the amplification processor 105. (0043) The aberration decision standard value setting part 102 is the part whereby the aberration decision standard value Th2 is set, which is the threshold value for determining the magnitude of the output signal amplitudes from the amplification processor 105. The aberration decision standard value setting part 102 automatically is set to a value found by multiplying the amplitude As of the output from the envelope detector 106 at time ts during the initial period of the table expansion process of said long tube 30 by a predetermined constant k; (where k.> 1).

(0044) The aforementioned comparative processor 103 compares the signal input from the amplification processor 105 with the aforementioned aberration decision standard value Th2, and outputs a high value generation signal when the signal of the amplification processor 105 is greater than the aberration decision standard value Th2. The notification means 110 notifies the operator via sound or display as to the occurrence of quality aberration when the aforementioned high value generation signal has been input.

[0045] Figure 6 and Figure 7 are waveform diagrams that give a schematic presentation of the outputs of each of the constitutive processors shown in Figure 5. Specifically, the figures are output waveform diagrams for each of the constitutive processors shown in Figure 5 when cracks occur in the connection 32b along with tube expansion of a long tube 30 having the constitution shown in Figure

[0046] The signal shown in Figure 6(a) is produced by conversion of the vibrations from the long tube into signals by the AE sensor 10. This waveform is the same as the waveform shown in Figure 3(a) and varies similarly. Specifically, an amplitude signal that is comparatively small is output from time to to time 1, as tube expansion of the steel tube 30a is occurring, whereas an amplitude signal waveform that is smaller than the waveform from time to to time 1, is output over the time period from time 1, to time to during which tube expansion of the weld region 31a occurs.

(0047) Subsequently, over the time period from time I<sub>2</sub> to time I<sub>3</sub> during which tube expansion of the steel tube 300 occurs, the AE sensor 10 outputs a signal waveform with an amplitude that is comparatively weak, as with the waveform output over the time period from I<sub>6</sub> to I<sub>4</sub> above. During the period from time I<sub>5</sub> to I<sub>4</sub> during which cracking occurs during tube expansion in the connection 31 b, a signal waveform with a comparatively large amplitude is output. Subsequently, a signal waveform with a comparatively small amplitude is output over the period from time I<sub>4</sub> to I<sub>5</sub> during which tube expansion of the tube 30e occurs. A signal waveform with a small amplitude is again output over the time period from time I<sub>5</sub> to I<sub>6</sub> during which the subsequent weld region is undergoing tube expansion (not shown in the figure).

(0048) The waveform shown in Figure 6(b) is the output signal from the absolute value processor 10, and results from removing the direct current component of the output signal from the AE sensor 10, and performing absolute value conversion. The waveform represented by the solid line in Figure 6(c) is the output signal from the envelope detector 106, and is produced as a result of processing the envelope from the outputs of the absolute value processor 101 in the manner described below.

[0049] Specifically, the periods from time t, to time t, time t, to time t, and time ts to time tt, are times when tube expansion is occurring in weld regions 31s, 31b, 31c... of the long tube, or times when aberrations are occurring. The envelopes for these times produce the waveforms represented by the broken lines in Figure 6(c), but the waveforms represented by said broken lines are not output in these time periods. Rather, values interpolated from the change in envelope intensity at a time before, after, or before and after (represented by the solid lines in the figure) are output as the envelope intensity At for said time points. (0050) For example, when the difference or ratio of the actual calculated value and the predicted value determined from the change in the envelope using the aforementioned standard exceeds a predetermined range, said predicted value is used instead of said actual value. Thus, the envelope intensities during tube expansion in the weld regions and during quality aberration will be far outside the values predicted from the transition of the envelope intensity during tube expansion of the main body of the steel tube, and so the aforementioned predicted values are used instead of the envelope intensity at these times

(0051) Figure 7(a) shows the output signal from the amplification processor 105. With regard to the output, the amplification processor 105 amplifies the signal shown in Figure 6(b) that is output by the absolute value processor 101 by a degree of amplification that is inversely proportional to the intensity of the envelope detector output represented by the solid line in Figure 6(c) in order to correct for damping of the elastic waves reaching the AE sensor. As is seen in the figure, the degree of amplification of the signal from the absolute value processor 101 is increased by the amplification processor 105 in accordance with the distance of the AE sensor from the site of tube expansion. An output is thus made after correcting for damping of the elastic waves produced by tube expansion.

{0052} Figure 7(b) shows the output signal from the comparative processor 103. The comparative processor 103 outputs a "Hi" signal when the output of the amplification processor exceeds the aforementioned aberration decision standard value 'Th2, and thus outputs pulse signals P1 to P3 which are high value generation signals during the period from time t3 to t4. The notification means 110 receives said high value generation signals, and uses sound or display to make a notification as to the occurrence of quality aberration.

[0053] In addition, a pulse counting processor is provided between the aforementioned comparative circuit part 105 [sic] and the aforementioned notification means 110, whereby the number of the aforementioned high value generation signals from the comparative processor 103 is counted. This number is then transmitted to the notification means 110. The notification means 110, thus renders notification regarding the occurrence of quality aberration and the degree of quality aberration based on the number of the high value generation is inenals.

(0054) Meanwhile, a peak value detector is provided that detects the maximum value for the amplification circuit output immediately after the point when the high value generation signal is output from the aforementioned comparative circuit 103. The notification means 110 thus renders notification as to the occurrence of quality aberration, and the degree of quality aberration based on the magnitude of said peak value.

(0055) Figure 8 is an output waveform diagram for each of the processors when cracking occurs during actual tube expansion of the steel tube. Specifically, the figure is an output waveform diagram when quality inspection is actually being carried out according to the present invention using the configuration described in Figure 1 and Figure 2(a). In (a), the high-amplitude output waveforms occurring approximately at times t<sub>1</sub>, t<sub>2</sub> and t<sub>3</sub> are generated due to the occurrence of cracking at these time points.

 $\{0056\}$  As is clear from the figures, when the aforementioned aberration decision standard value Th1 is set to 5x the value of the amplitude As of the AE sensor at time ts in the initial period of tube expansion using the aforementioned aberration decision standard value setting part 102, the comparative processor 103, as shown in (b) generates puise signals which are the aforementioned high value generation signals, the first being close to time  $t_1$ , the second being close to time  $t_2$  and the third being close to time  $t_3$ . On second being close to time  $t_4$  the second being close to time  $t_5$  and the third being close to time  $t_5$ . Consequently, the notification means sends notification of aberration occurrences at these time points  $t_1$ ,  $t_2$  and  $t_3$ .

(0057) The present invention is not restricted by the embodiments described above, and various modifications are possible within a range that does not exceed the scope of the invention. For example, it goes without saying that the steel tube that is the subject of inspection is not restricted to one that has weld regions. The site of attachment of the AE sensor is also not restricted to the side surface of the tube, as the sensor may be attached at the end surface. In the embodiments described above, the tube expansion mandrel had a tapered region, but mandrels are not restricted to this type. For example, a tube expansion mandrel can be used that has expanding diameter rollers present on the

outer surface of the mandrel, so that the internal wall of the steel tube is pressed outwards in a radial direction by means of said expanding diameter rollers.

(0058) On the other hand, regarding setting of the aforementioned aberration decision standard value, modes are not restricted to the process represented in the embodiment, and the value may be set on a value that is between the amplitude of the signal determined when normal tube expansion is occurring and the amplitude of the signal determined when quality aberration occurs. In addition, in the aforementioned embodiment, processing performed by analog signal processors can be carried out by means of digital signal processing. For example, an A/D converter can be provided after the absolute value processor 101 or the amplification processor 105 so that their outputs are converted to digital signals, which are then subjected to digital signal processing for subsequent processes.

Effects of the Invention) By means of the quality inspection method used during tube expansion described in Claim 1 of the present invention, as tube expansion occurs with movement of the tube expansion mandrel, vibrations are generated at the site of tube expansion. When quality aberrations are generated in the steel tube, the AE sensor signal amplitude increases relative to the amplitude at previous and subsequent time points. By employing this increase, the invention has the ment of allowing determination regarding an occurrence of quality aberration as tube expansion occurs without installing special irradiation devices or drive devices for quality inspection.

(0060) In addition, vibrations generated by tube expansion and by movement of the tube expansion device are transmitted through the steel tube to an AB sensor that is at a location distant from the site where tube expansion is occurring, so that it is possible to perform quality inspection during tube expansion with the inspection device itself fixed at a specific location. In addition, there is also the merit that quality inspection can be carried out as the long steel tube is undergoing expansion. Because the rate of transmission of said vibrations is extremely fast, when quality aberrations such as cracking occur during tube expansion, it is possible to detect the occurrence of quality aberration and the degree of quality aberration nearly simultaneous to its occurrence.

(9061) Moreover, with the quality inspection method used during tube expansion described in Claim 2, in addition to the merits of the quality inspection method described in Claim 1, there is the merit that the degree of quality aberration can be determined simultaneous to the quality aberration with the inspection device itself fixed at a determined location, without requiring the use of special drive devices or irradiation devices for quality inspection.

[0062] Moreover, with the quality inspection method used during tube expansion described in Claim 3, the degree of amplification of the AE sensor is increased in accordance with a continual decrease in AE sensor signal amplitude, or the degree of amplification of the AE sensor signal is decreased in accordance with a continual increase in AE sensor amplitude. By this means, damping of the elastic waves generated due to tube expansion occurring during the time it takes them to reach the AE sensor can be compensated for with high precision, so that it is possible to increase the reliability and accuracy of processing carried out using said AE sensor signal.

(9063) For example, as the tube expansion mandrel becomes increasingly distant from the AE sensor, the decrease in AE sensor signal is compensated for, and thus even with long steel tubes, it is possible to determine the occurrence of quality aberration and the degree of quality aberration with a high level of accuracy. Moreover, because stable determination of the occurrence of quality aberration and the degree of quality aberration is possible with little fluctuation in AE sensor signal amplitude due to change in transmission distance, a quality inspection method for use during tube expansion is provided that increases the reliability of these determinations.

(Bird Description of the Figures)

Figure 1) Schematic constitutional diagram that presents a summary of the quality inspection method during tube expansion of steel tubes pertaining to the present invention.

{Figure 2} Control block diagram showing an example of the signal processing system for the steel tube quality inspection device used in the present invention.

(Figure 3) Diagram giving a schematic presentation of the signal waveforms for each of the processors of Figure 2(a), (b) and (c), where (a) is the waveform diagram of the output signal from the

AE sensor, (b) is the waveform diagram of the output signal from the absolute value processor and (c) is the waveform diagram of the output signal from the comparative processor.

(Figure 4) Diagram giving a schematic presentation of the signal waveforms for each of the processors for Figure 2(d), where (a) is the waveform diagram of the output signal from the AE sensor, (b) is the waveform diagram of the output signal from the absolute value processor and (c) is the waveform diagram of the output signal from the envelope detector.

{Figure 5} Control block diagram showing an example of a processing system other than that of the steel tube quality inspection device presented in Figure 2(a)-(d).

(Figure 6) Waveform diagrams giving a schematic presentation of the outputs of the constitutive processors for the steel tube quality inspection device shown in Figure 5, where (a) is the waveform diagram of the output signal from the AE sensor, (b) is the waveform diagram of the output signal from the absolute value processor and (c) is the waveform diagram of the output signal from the envelope detector.

(Figure 7) Waveform diagrams giving a schematic presentation of the outputs of the constitutive processors for the steel tube quality inspection device shown in Figure 5, where (a) is the waveform diagram of the output signal from the amplification processor and (b) is the waveform diagram of the output signal from the comparative processor.

[Figure 8] Waveform diagrams for the various processors when cracking occurs during actual tube expansion of a steel tube, where (a) is the output waveform diagram from the absolute value processor and (b) is the output waveform diagram from the comparative processor and (b) is the output waveform diagram from the comparative processor.

```
{Kev}
10
        AE sensor
20
        Tube expansion mandrel
30
        Long tube
30a, 30b, 30c... Steel tubes
31a, 31b...Weld regions
100
       Quality inspection device unit
101
        Absolute value processor
102
       Aberration decision standard value setting part
103
       Comparative processor
104
       Pulse calculator
105
       Amplification processor
106
       Envelope detector
107
       Peak value detector
108
       Pulse width determination part
110
       Notification means
```

### Figure 1

Figure 3
(a)
AE sensor output
Time
(b)
Absolute value processor output
Time

[see source for figures]

Comparative processor output Time

```
Figure 5
[see Key above]
Figure 2
[sec Key above]
Figure 4
(a)
AE sensor output
Time
Absolute value processor output
Time
(c)
Envelope detector output
Time
Figure 6
AE sensor output
Time
(b)
Absolute value processor output
Time
(c)
Envelope detector output
Time
Figure 7
(a)
Amplification processor output
Time
(b)
Comparative processor output
Time
Figure 8
Comparative value processor output
Time
(b)
Comparative processor output
Time
Continued from the front page
F Terms (Reference)
                     [see source for codes]
```



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Sworn to before me this 23rd day of January 2002.

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